JOURNAL OF THE KENTUCKY ACADEMY OF SCIENCE

Official Publication of the Academy

Volume 63
Number 1
Spring 2002

The Kentucky Academy of Science

Founded 8 May 1914

All manuscripts and correspondence concerning manuscripts should be addressed to the Editor.

The JOURNAL is indexed in BIOSIS, Cambridge Scientific Abstracts, Selected Water Resource Abstracts, *State Academies of Science Abstracts, and Zoological Record.*

Membership in the Academy is open to interested persons upon nomination, payment of dues, and election. Application forms for membership may be obtained from the Secretary. The JOURNAL is sent free to all members in good standing.

Annual dues are \$25.00 for Active Members; \$15.00 for Student Members; \$35.00 for Family; \$350.00 for Life Members. Subscription rates for nonmembers are: \$50.00 domestic; \$60.00 foreign. Back issues are \$30.00 per volume.

The JOURNAL is issued semiannually in spring and fall. Two numbers comprise a volume.

Correspondence concerning memberships or subscriptions should be addressed to the Executive Secretary.

∞ This paper meets the requirements of ANSI/NISO Z39.48-992 (Permanence of Paper).

JOURNAL OF THE KENTUCKY ACADEMY OF SCIENCE
ISSN 1098-7096

Continuation of
Transactions of the Kentucky Academy of Science

Volume 63 Spring 2002 Number 1

J. Ky. Acad. Sci. 63(1):1–7. 2002.

The Taxonomy, Variation, and Distribution of Worm Snakes, Genus *Carphophis* (Reptilia: Colubridae), in Kentucky

Les Meade

Department of Biological and Environmental Sciences, Morehead State University, Morehead, Kentucky 40351

ABSTRACT

Two subspecies of worm snakes, genus *Carphophis,* occur in Kentucky. *Carphophis amoenus amoenus,* the eastern worm snake, frequents eastern and central Kentucky. *Carphophis a. helenae,* the midwest worm snake, occurs almost statewide, except for portions of the Bluegrass and Western Coal Field. Where these two races overlap, there is a broad intergrade zone; this zone is much wider than previously indicated. Intergrades range from Meade, Hardin, and Edmonson counties eastward to Pike County and southward to Clinton, Bell, Harlan, and Letcher counties. External morphology in these snakes is very similar. Identification is based on head scale patterns. There are two internasals and two prefrontals in *amoenus,* two internasals in *helenae,* and partial fusion of scales in intergrades. Sexual dimorphism in these snakes is obvious when examined statistically. Mean number of ventrals and snout-vent length/total length were greater in females. Mean number of caudals and tail length/total length were greater in males.

INTRODUCTION

Two subspecies of worm snakes, genus *Carphophis,* occur in Kentucky: *C. a. amoenus* (Say), the eastern worm snake, and *C. a. helenae* (Kennicott), the midwest worm snake (Ernst and Barbour 1989). Recent range maps for these snakes are given by Conant and Collins (1998). *Carphophis a. amoenus* occurs throughout the eastern United States. *Carphophis a. helenae* ranges across eastern and midwestern states. Scale patterns, body size and proportions, and coloration are very similar in these snakes. *Carphophis a. amoenus* and *C. a. helenae* differ only in head scutellation, with *amoenus* having separate internasals and prefrontals, and *helenae* having their internasals and prefrontals fused into two larger internasals. A related species, *C. vermis,* the western worm snake, occurs west of the Mississippi River, except for populations in eastern Illinois and southwestern Wisconsin (Clark 1968; Conant and Collins 1998).

Thomas Say described *Coluber amoenus* in 1825, based on specimens from "Pennsylvania." The type locality was later restricted to "vicinity of Philadelphia" by Schmidt (1953). In the Kentucky literature, S. Garman (1883) and H. Garman (1894) both placed this snake in the genus *Carphophis*; E.D. Cope (1896, 1900) used the genus name *Carphophiops.* All other authors referring to Kentucky specimens have listed this snake in the genus *Carphophis.* H. Garman (1894) listed both *Carphophis amoenus* and *C. helenae* for Kentucky, and cited an intermediate form (intergrade) from Tyrone, Kentucky (Anderson County). Funkhouser (1925, 1945) also listed both forms for Kentucky. Blanchard (1925) examined *Carphophis* and found the main distinguishing characteristics to be as follows: number of head scales anterior to the frontal scale (4 in *amoenus* and *vermis,* 2 in *helenae*), number of posterior temporals (2 in *amoenus* and *helenae,* 1 in *vermis*), and variation in coloration (with light ventral color reaching the sec-

Table 1. Sexual dimorphism in Kentucky specimens of *Carphophis amoenus amoenus*. Specimens included 29 males and 25 females.

Character	Range	Mean	P
Total length (TL)			
Males	155–244	214.1	NS
Females	91–273	217.1	
Ventrals			
Males	112–119	115.7	**
Females	116–128	122.3	
Caudals			
Males	33–40	35.7	**
Females	24–31	27.6	
Tail length/TL			
Males	0.169–0.200	0.188	**
Females	0.126–0.158	0.143	
Snout–vent length/TL			
Males	0.800–0.831	0.812	**
Females	0.842–0.874	0.857	

* = Significance ($P < 0.05$); ** = high significance ($P < 0.01$); NS = no significance.

Table 2. Sexual dimorphism in Kentucky specimens of *Carphophis amoenus helenae*. Specimens included 37 males and 32 females.

Character	Range	Mean	P
Total length (TL)			
Males	93–257	212.1	NS
Females	88–288.5	216.0	
Ventrals			
Males	108–122	115.6	**
Females	119–133	124.2	
Caudals			
Males	32–41	35.7	**
Females	25–31	27.9	
Tail length/TL			
Males	0.170–0.219	0.189	**
Females	0.130–0.155	0.142	
Snout–vent length/TL			
Males	0.781–0.830	0.811	**
Females	0.845–0.870	0.859	

* = Significance ($P < 0.05$); ** = high significance ($P < 0.01$); NS = no significance.

ond scale row in *amoenus* and *helenae*, and the third row in *vermis*). Dury and Williams (1933) listed an intergrade specimen from Knox County. Bailey (1933), Burt (1933), and Welter and Carr (1939) reported additional records of *helenae*. Hibbard (1936) found both *amoenus* and *helenae* in the Mammoth Cave region. Smith (1948) reported on a population of *Carphophis* from Middlesboro, Bell County, and noted the presence of intergrades. Barbour (1950a) found *amoenus*, *helenae*, and intergrade worm snakes on Big Black Mountain, Harlan County. Barbour (1950b, 1960) summarized records of worm snakes from Kentucky. In 1950b, he reported intergrades from Harlan, Letcher, Fleming, and Rowan counties. In 1960, he added intergrade records for Bath, Carter, McCreary, and Whitley counties. He also indicated that (1) intergrades occur at the western edge of the mountains (escarpment region) and (2) that there is some evidence that worm snakes in western Kentucky are intermediate between *helenae* and *vermis*. Bush (1957, 1959) found *amoenus*, *helenae*, and intergrades in Clemons Fork, Breathitt County. Von Allmen (1976) and Westerman and Westerman (1980) reported *helenae* as part of the Breckinridge County herpetofauna.

The major objectives of this study were to (1) examine the taxonomic characteristics of *C. a. amoenus* and *C. a. helenae* in Kentucky, (2) describe sexual dimorphism and intraspecific variation in these snakes, (3) summarize distributional records for these snakes, and (4) define their intergrade zone.

MATERIALS AND METHODS

Data were gathered from preserved specimens, available literature, and additional unpublished field notes and maps prepared over the past 25 years. Specimens examined came from collections at Kentucky colleges and universities, collections at universities and natural history museums outside of Kentucky, and from private herpetological collections. Complete morphometric and meristic data were collected from 147 specimens of *Carphophis amoenus*, but heads of 533 additional specimens were examined to look for intergrades. Morphometric characters examined included total length, tail length, snout-vent length, tail length/total length, and snout-vent length/total length. Total length and tail length were measured to the nearest half millimeter. Total length was recorded as the distance from the tip of the snout to the posterior tip of the tail. Tail length was recorded as the distance from the posterior edge of the anal plate to the tip of the tail. Snout-vent length/total length and tail length/total length were calculated to in-

Table 3. Intraspecific variation in Kentucky specimens of *Carphophis amoenus ameonus* and *Carphophis amoenus helenae*. Specimens included 54 *amoenus* and 69 *helenae*.

Character	Range	Mean	*P*
Total length (TL)			
amoenus	161–273	221.3	NS
helenae	166–289	223.8	
Ventrals			
amoenus	112–128	118.7	NS
helenae	108–133	119.4	
Caudals			
amoenus	25–40	32.1	NS
helenae	25–40	32.1	
Tail length/TL			
amoenus	0.129–0.200	0.168	NS
helenae	0.130–0.219	0.167	
Snout–vent length/TL			
amoenus	0.800–0.871	0.832	NS
helenae	0.781–0.870	0.833	
Hemipenis Length			
amoenus	6–8	6.87	NS
helenae	6–9	7.33	

* = Significance ($P < 0.05$); ** = high significance ($P < 0.01$); NS = no significance.

Table 4. Sexual dimorphism in Kentucky specimens of *Carphophis amoenus amoenus* × *helenae*. Specimens included 10 males and 14 females.

Character	Range	Mean	*P*
Total length (TL)			
Males	183–251	212.2	NS
Females	167–246	215.2	
Ventrals			
Males	111–120	115.3	**
Females	117–129	123.3	
Caudals			
Males	34–39	36.0	**
Females	25–32	28.0	
Tail length/TL			
Males	0.180–0.200	0.190	**
Females	0.130–0.157	0.145	
Snout–vent length/TL			
Males	0.800–0.820	0.810	**
Females	0.843–0.870	0.855	

* = Significance ($P < 0.05$); ** = high significance ($P < 0.01$); NS = no significance.

dicate percentage of snout-vent length and tail length, respectively.

Meristic characters examined included the number of dorsal scale rows, ventrals, caudals, scales in the anal plate, supralabials, infralabials, nasals, loreals, preoculars, postoculars, suboculars, temporals, internasals, and prefrontals. Scale counts were taken on both sides of the head when possible. Observed characters included the presence or absence of keeling on scales, presence or absence of apical stigmata, presence or absence of an apical notch, hemipenis size and structure, and body coloration. Meristic characters were collected by using a Bausch and Lomb dissecting microscope fitted with 10× oculars and a 3× zoom for a maximum magnification of 30×.

Statistical analysis of data was used to compare specific characters for sexual dimorphism and intraspecific variation. Student's-*t* test was used because of small sample size; means of all characters were compared at the 0.05 and 0.01 significance levels.

RESULTS AND DISCUSSION

Carphophis a. amoenus

Size and proportions in *C. a. amoenus* are summarized as follows: total length of specimens examined ranged from 91 to 273 mm; tail length, from 11.5 to 48 mm; snout-vent length, from 79.5 to 236 mm; ratio of snout-vent length/total length, from 0.800 to 0.874; and ratio of tail length/total length, from 0.126 to 0.200.

Scutellation in *C. a. amoenus* is as follows: dorsal scales smooth; apical stigmata single; apical notch absent; dorsal scale rows 13-13-13 (100%); head plates normal; nasals 1 (100%); loreals 1 (100%); loreal and prefrontal form anterior boundary of eye; preoculars absent (94.4%), or rarely 1 (5.6%); postoculars 1 (100%); temporals usually 1+2 (95.3%), rarely 1+1 (3.8%) or 1+3 (0.9%); supralabials 5 (100%); infralabials usually 6 (99.1%), rarely 5 (0.9%); ventrals 112–128 (mean 118.7); caudals 24–40 (mean 32.1); and anal plate divided.

Sexual dimorphism in specimens of *C. a. amoenus* is summarized in Table 1. Mean number of ventrals, number of caudals, tail length/total length and snout-vent length/total length were significantly different between males and females. Mean number of caudals (35.7/27.6) and tail length/total length (0.188/0.143) were greater in males. Mean number of ventrals (115.7/122.3) and snout-vent length/total length (0.812/0.857) were greater in females. Mean total length did not signifi-

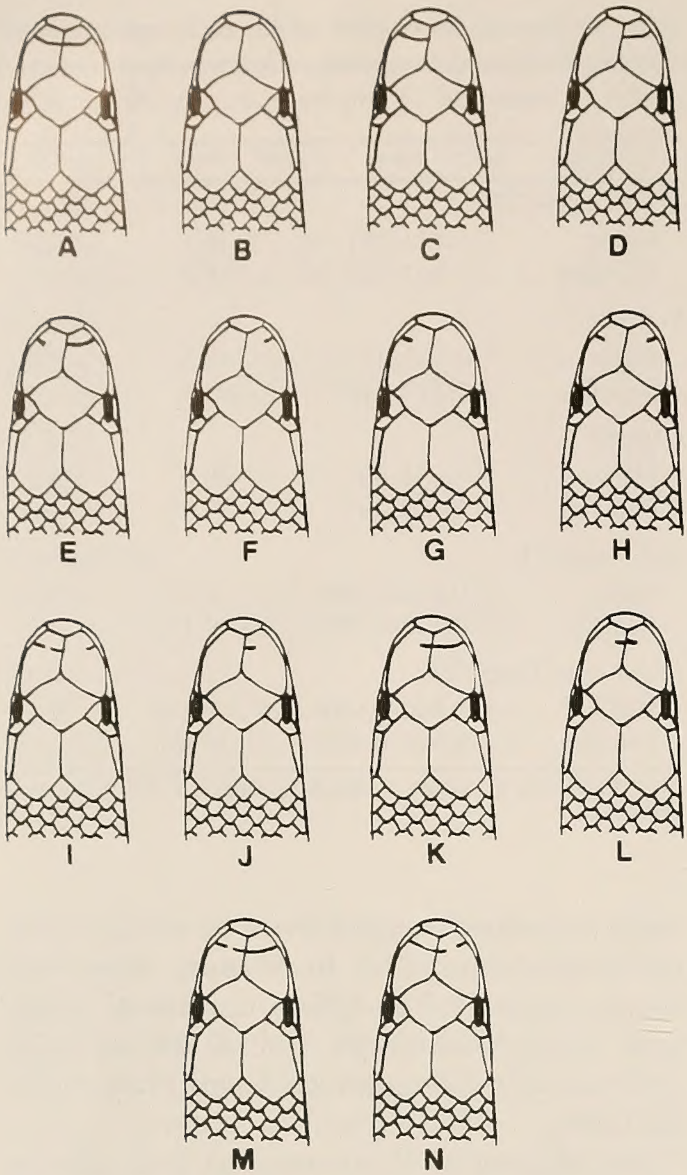


Figure 1. Dorsal head scales in worm snakes, genus *Carphophis*. A. *C. amoenus amoenus*. B. *C. amoenus helenae*. C–N. *C. amoenus amoenus* × *helenae* intergrades.

cantly differ with regard to sex. Anal ridges were present on 96.6% of males examined, but absent on all females. The only male specimen without anal ridges was a juvenile with a total length of 161 mm (CM 44601). Blanchard (1931) reported anal ridges on 88% of males and 0% of females; he found no anal ridges on most male specimens less than 180 mm in total length. Clark (1970) found anal ridges on 81% of males and 4% of females.

Clark (1966) indicated that fossorial snakes (including *Carphophis*) have shortened tails and a high degree of sexual dimorphism. Reduction of tail length in burrowing males is less than females because of the male hemipenes and associated muscles. Clark (1966) found a coefficient of divergence (CD) of 28% for *Carphophis*, where CD = the difference between the mean tail length for males and females divided by one-half of their sum × 100. Clark (1966) reported highest CD values for snakes in the genera *Virginia, Heterodon, Carphophis,* and *Farancia,* all of which include species that are burrowers.

Carphophis a. helenae

Size and proportions in *C. a. helenae* are described as follows: total length of specimens examined ranged from 88 to 288.5 mm; tail length, from 12 to 51 mm; snout-vent length, from 75 to 245.5 mm; ratio of snout-vent length/total length, from 0.781 to 0.870; and ratio of tail length/total length, from 0.130 to 0.219.

Scutellation in *C. a. helenae* is as follows: dorsal scales smooth; apical stigmata single; apical notch absent; dorsal scale rows 13-13-13 (100%); parietals, frontal, and supraoculars normal; prefrontals fused with adjacent internasals to form two large internasal plates; nasals 1 (100%); loreals 1 (100%); loreal and internasal form anterior boundary of eye; preoculars absent (100%); postoculars usually 1 (97.9%), rarely 2 (0.7%) or absent (1.4%); temporals usually 1+2 (77.0%), occasionally 1+1 (23.0%); supralabials usually 5 (97.2%), rarely 4 (0.7%) or 6 (2.1 %); infralabials 6 (100%); ventrals 108–133 (mean 119.4); caudals 25–41 (mean 32.1); and anal plate divided.

Sexual dimorphism in *C. a. helenae* was not obviously different from that shown by *C. a. amoenus* (Table 2). Mean number of ventrals, number of caudals, tail length/total length and snout-vent length/total length were significantly different between the sexes. Mean number of caudals (35.7/27.9) and tail length/total length (0.189/0.142) were greater in males. Mean number of ventrals (115.6/124.2) and snout-vent length/total length (0.811/0.859) were greater in females. Mean total length did not significantly differ with regard to sex. Anal ridges were present on 91.9% of males and 6.3% of females examined. Three males without anal ridges were all less than 125 mm in total length. Blanchard (1931) reported anal ridges on 71% of males and 17% of females; he found that most males without anal ridges were less than 180 mm. Clark (1970) found anal ridges on 81% of males and 19% of females.

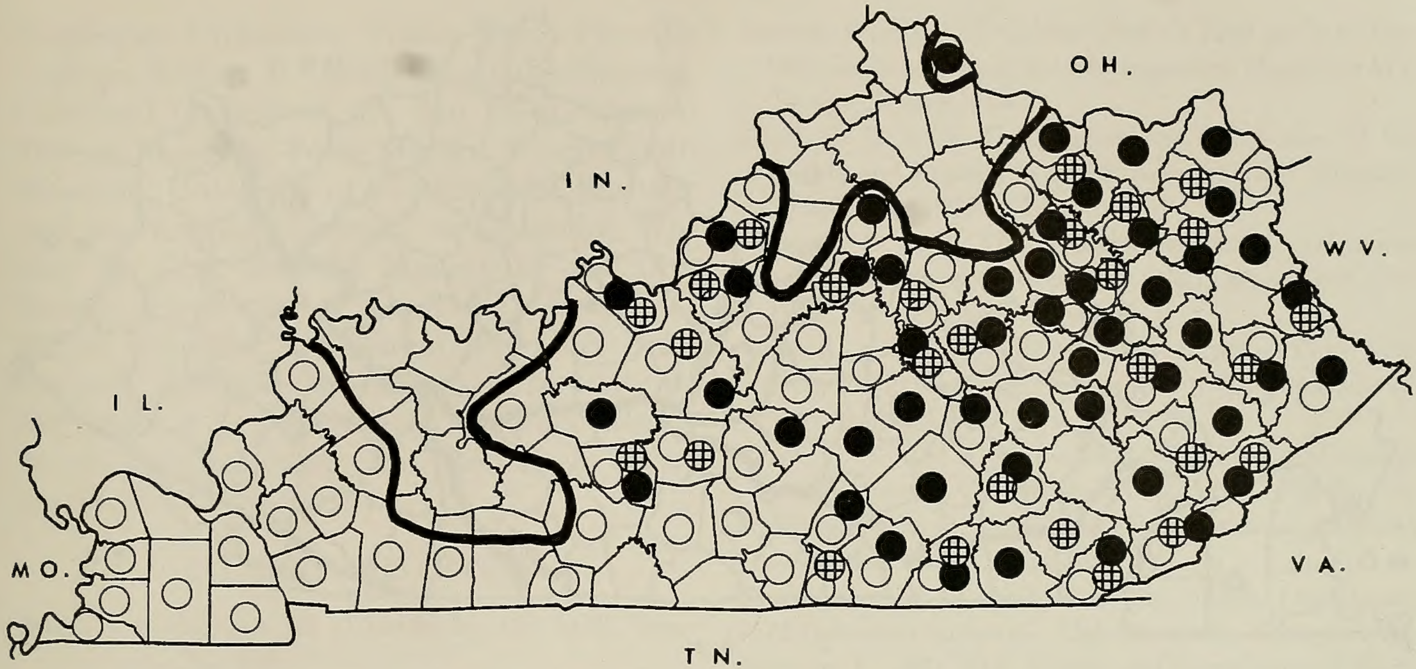


Figure 2. Distribution of the eastern worm snake, *Carphophis amoenus amoenus* (solid circles) and midwest worm snake, *C. amoenus helenae* (open circles) in Kentucky. Intergrades shown as cross-hatched circles. Black lines indicate that *C. amoenus* is absent from portions of the Bluegrass and Western Coal Field.

Intraspecific variation in Kentucky specimens of *C. a. amoenus* and *C. a. helenae* is indicated in Table 3. Mean total length, number of ventrals, number of caudals, tail length/total length, snout-vent length/total length, and hemipenis length were not significantly different between these subspecies.

Carphophis a. amoenus × *helenae*

Sexual dimorphism in *C. a. amoenus* × *helenae* is summarized in Table 4. Mean number of ventrals, number of caudals, tail length/total length, and snout-vent length/total length were significantly different between males and females. Mean number of caudals (36.0/28.0) and tail length/total length (0.190/0.145) were greater in males. Mean number of ventrals (115.3/123.3) and snout-vent length/total length (0.810/0.855) were greater in females. Mean total length did not significantly differ with regard to sex. Anal ridges were present on 83.3% of males examined, but absent on all females. The only male specimens without anal ridges were juveniles with a total length of 92–108 mm.

Head scale patterns in specimens of *C. a. amoenus* × *helenae* are as follows for 47 intergrade specimens; internasals and prefrontals separate on right (23.4%); internasals and prefrontals separate on left (14.9%); internasals partially divided on one side (25.5%); internasals partially divided on both sides (14.9%); and internasals and prefrontals separate on one side, and partially divided on the other (21.3%) (Figure 1).

SUMMARY AND CONCLUSIONS

Carphophis a. amoenus frequents the Cumberland Plateau, Cumberland Mountains, southern one-half of the Bluegrass, eastern and northern Mississippian Plateau, and eastern edge of the Western Coal Field. *Carphophis a. helenae* occurs almost statewide and intergrades with *C. a. amoenus* across a zone that covers much of eastern and central Kentucky (Figures 2, 3). Both *amoenus* and *helenae* are absent from the northern one-half of the Bluegrass and much of the Western Coal Field (Figure 2). Range maps given by Conant and Collins (1991, 1998) are inaccurate because they show the intergrade zone for Kentucky occurring only in northeastern Kentucky. In fact, intergrades range from Meade, Hardin and Edmonson counties eastward to Pike County and southward to Clinton, McCreary, Bell, Harlan, and Letcher counties (Meade 1991a, 1991b, 1993).

A summary of 12 taxonomic characters indicated the similarity between these two subspecies, and showed that head scutellation (with regard to internasals and prefrontals) is the only obvious difference between *C. a.*

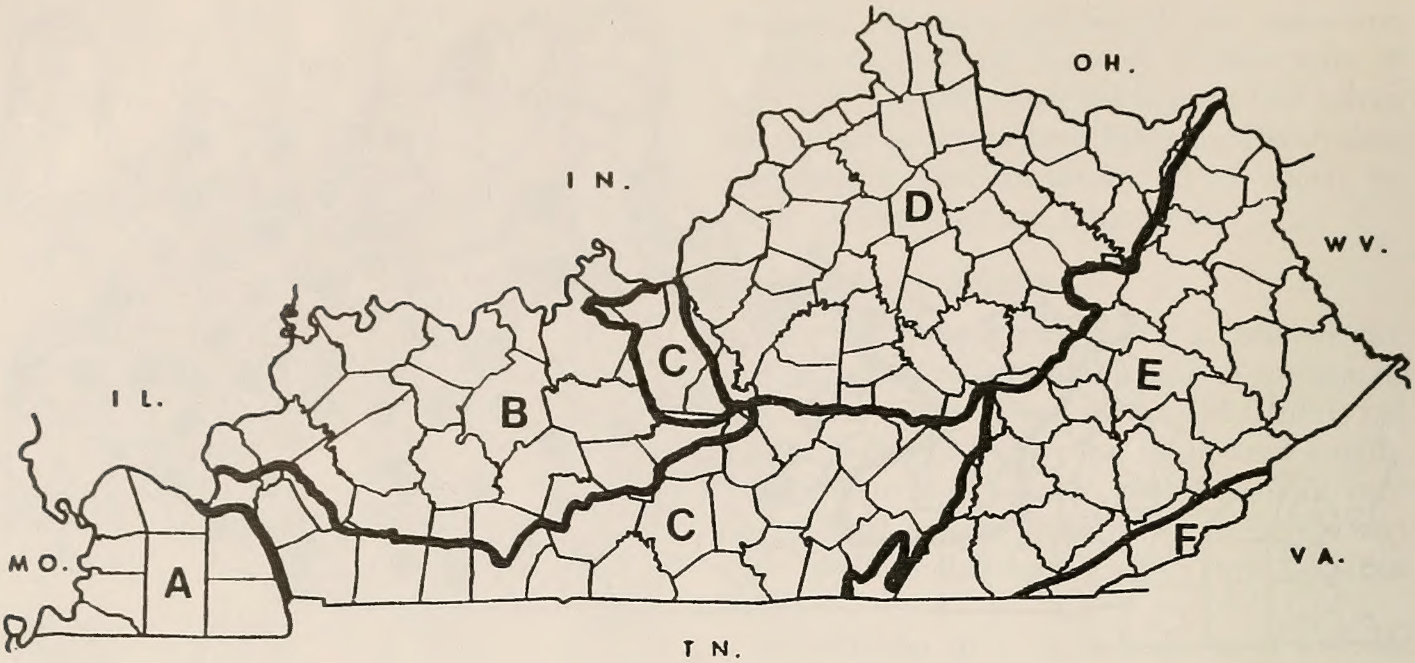


Figure 3. Kentucky physiographic regions. A. Jackson Purchase. B. Western Coal Field. C. Mississippian Plateau. D. Bluegrass. E. Cumberland Plateau. F. Cumberland Mountains.

amoenus and *C. a. helenae* (Table 5). *Carphophis a. helenae* also has a higher percentage of specimens with one posterior temporal; 23.0% in *helenae* and 3.8% in *amoenus*.

ACKNOWLEDGMENTS

Special thanks to Woodrow W. Barber who kindled my interest in worm snakes. I am also grateful to the following persons for allowing access to collections, lending specimens, and/or providing information: Charles W. Myers, American Museum of Natural History; Thomas Uzzell and Edmond V. Malnate, Academy of Natural Sciences, Philadelphia; David H. Snyder and Floyd Scott, Austin Peay State University; Clarence J. McCoy, Carnegie Museum of Natural History; Richard Davis, Cincinnati Museum of Natural History; Hymen Marx and Harold K. Voris, Field Museum of Natural History; M.A. Morris, Illinois Natural History Survey; James C. List, Ball State University; John R. MacGregor, personal collection, field notes, and maps; John W. Wright and Fred S. Truxal, Los Angeles County Museum; Pere Alberch and Jose Rosado, Museum of Comparative Zoology, Harvard University; Paul M. Daniel, Miami University; C.D. Wilder, Murray State University; John M. Condit, Museum of Zoology, The Ohio State University; Henri C. Seibert, Ohio University

Table 5. Comparison of taxonomic data in Kentucky specimens of *Carphophis amoenus amoenus* and *Carphophis amoenus helenae*. Specimens included 54 *amoenus* and 69 *helenae*. IN = intenasals; PF = prefrontals.

Character	*C. a. amoenus*	*C. a. helenae*
Total length (TL)	88–289 mm	91–273 mm
Tail length	12–51 mm	11.5–48 mm
Snout–vent length	75–245.5 mm	79.5–236 mm
Tail length/TL	0.130–0.219	0.126–0.200
Snout–vent length/TL	0.781–0.870	0.800–0.878
Ventrals	108–133	112–128
Caudals	25–41	24–40
Dorsal scale rows	13-13-13	13-13-13
Supralabials	5	5
Infralabials	6	6
Post. temporals 1	3.8%	23.0%
Coloration	M to D brown; pinkish belly	M to D brown; pinkish belly
Hemipenis length	6–8 scales	6–9 scales
Head scales	IN and PF separate	IN and PF fused

Vertebrate Collection; Foster Levy, Pikeville College; Robert E. Todd, personal collection; Crawford G. Jackson, Jr., San Diego Natural History Museum; Peter Meylan, Florida State Museum, University of Florida; R.W. Barbour and Jim Krupa, University of Kentucky; William M. Clay, Burt L. Monroe Jr. and Bob Brown, University of Louisville; Arnold G. Kluge, Ronald A. Nussbaum, and Gary Breitenbach, Museum of Zoology, University of Michigan; R.W. McDiarmid, National Museum of Natural History; and Bob Hoyt, Western Kentucky University.

LITERATURE CITED

Bailey, V. 1933. Cave life of Kentucky. Am. Midl. Naturalist 14(5):385–635.

Barbour, R. W. 1950a. The reptiles of Big Black Mountain, Harlan County, Kentucky. Copeia 1950(2):100–107.

Barbour, R. W. 1950b. The distribution of *Carphophis amoena* in Kentucky. Copeia 1950(3):237.

Barbour, R. W. 1960. A study of the worm snake, *Carphophis amoenus* Say, in Kentucky. Trans. Kentucky Acad. Sci, 21(1–2):10–16.

Blanchard, F. N. 1925. The forms of *Carphophis*. Papers Michigan Acad. Sci. 4(1):527–530.

Blanchard, F. N. 1931. Secondary sex characters of certain Snakes. Bull. Antivenin Inst. Am. 4(4):95–104.

Burt, C. E. 1933. A contribution to the herpetology of Kentucky. Am. Midl. Naturalist 14(6):669–679.

Bush, F. M. 1957. A survey of the herpetofauna of Clemons Fork, Breathitt County, Kentucky. M.S. thesis. University of Kentucky, Lexington, KY.

Bush, F. M. 1959. The herpetofauna of Clemons Fork, Breathitt County, Kentucky. Trans. Kentucky Acad. Sci. 20(1–2):11–18.

Clark, D. R., Jr. 1966. Notes on sexual dimorphism in tail-length in American snakes. Trans. Kansas Acad. Sci. 69(3–4):226–232.

Clark, D. R., Jr. 1968. A proposal of specific status for the western worm snake, *Carphophis amoenus vermis* (Kennicott). Herpetologica 24(2):104–112.

Clark, D. R., Jr. 1970. Ecological study of the worm snake *Carphophis vermis* (Kennicott). Publ. Mus. Nat. Hist. Univ. Kansas 19(2):85–194.

Conant, R., and J. T. Collins. 1991. A field guide to reptiles and amphibians. 3rd ed. Houghton Mifflin Co., Boston, MA.

Conant, R., and J. T. Collins. 1998. A field guide to reptiles and amphibians. 3rd ed., expanded. Houghton Mifflin Co., Boston, MA.

Cope, E. D. 1896. The geographical distribution of Batrachia and Reptilia in North America. Am. Naturalist 30:886–902, 1003–1026.

Cope, E. D. 1900. The crocodilians, lizards, and snakes of North America. Rep. U.S. Natl. Mus. 1898:153–1270.

Dury, R., and R. S. Williams. 1933. Notes on some Kentucky amphibians and reptiles. Baker-Hunt Foundation Mus. Bull. 1:1–22.

Ernst, C. H., and R. W. Barbour. 1989. Snakes of eastern North America. George Mason Univ. Press, Fairfax, VA.

Funkhouser, W. D. 1925. Wild life in Kentucky. Kentucky Geological Survey, Frankfort, KY.

Funkhouser, W. D. 1945. Kentucky snakes. Department of University Extension, Univ. Kentucky, Lexington, KY.

Garman, S. 1883. The reptiles and batrachians of North America. Part I. Ophidia. Mem. Mus. Comp. Zool. 8(3): 1–185.

Garman, H. 1894. A preliminary list of the vertebrate animals of Kentucky. Bull. Essex Inst. 26(1–3):1–63.

Hibbard, C. W. 1936. The amphibians and reptiles of Mammoth Cave National Park proposed. Trans. Kansas Acad. Sci. 39:277–281.

Meade, L. E. 1991a. Kentucky snakes: their systematics, variation, and distribution. J. Tennessee Acad. Sci. 66(4):175–182.

Meade, L. E. 1991b. The systematics, distribution and variation of worm snakes, genus *Carphophis* in Kentucky. Trans. Kentucky Acad. Sci. 52(1–2):85 (abstract).

Meade, L. E. 1993. Kentucky snakes: their systematics, variation and distribution. Ph.D. dissertation. Univ. Southern Mississippi, Hattiesburg, MS.

Say, T. 1825. Descriptions of three new species of *Coluber*, inhabiting the United States. J. Acad. Nat. Sci. Philadelphia 4(2):237–241.

Schmidt, K. P. 1953. A check list of North American amphibians and reptiles. 6th ed. Univ. Chicago Press, Chicago, IL.

Smith, A. G. 1948. Integradation in worm snakes (*Carphophis*) from Kentucky. Nat. Hist. Misc. 18:1–3.

Von Allmen, G. A. 1976. Snakes of Breckinridge County, Kentucky. Kentucky Herpetol. 7(1):4–7.

Welter, W. A., and K. Carr. 1939. Amphibians and reptiles of northeastern Kentucky. Copeia 1939(3):128–130.

Westerman, A., and D. Westerman. 1980. Herptile collections in Breckinridge County, Kentucky. Kentucky Herpetol. 8(1):4–5.

J. Ky. Acad. Sci. 63(1):8–18. 2002.

Abundance of Non-target, Stem-dwelling Arthropods in Central Hardwood Forests of Kentucky Treated for Gypsy Moth

L. K. Rieske and L. J. Buss[1]

Department of Entomology, University of Kentucky, Lexington, Kentucky 40546-0091

ABSTRACT

We assessed the abundance of non-target, stem-dwelling arthropods in forested areas of the Cumberland Plateau that received applications of *Bacillus thuringiensis* var. *kurstaki* (*Btk*) and diflubenzuron, simulating gypsy moth suppression programs, and compared to untreated controls. Study plots in southeastern Kentucky were aerially sprayed one time in May 1997; control plots were not sprayed. In 1997 and 1998, we sampled arthropods in strata ranging from ground level to the forest canopy. Here we report the effects of the treatments on stem-dwelling arthropods sampled with funnel and stem traps in 1997 and 1998. A single application of *Btk* and diflubenzuron had minimal impact on non-target, stem-dwelling arthropods assessed by our methods and bark/ambrosia beetles (Coleoptera: Scolytidae) trapped in stem traps were the only group to demonstrate reduced abundance in treated plots. In funnel traps, spatial and temporal differences in abundance of several taxa were evident, independent of site treatments. Bark/ambrosia beetles were the most abundant taxon trapped in funnel traps. In stem traps, ground beetles (Coleoptera: Carabidae) were the most abundant taxon trapped. Again, spatial and temporal differences in abundance of most groups were evident, independent of site treatments.

INTRODUCTION

The gypsy moth, *Lymantria dispar* (L.) (Lepidoptera: Lymantriidae), is an introduced forest defoliator with outbreak potential that has become established throughout the northeastern United States and continues to expand its range. The successful southward and westward expansion of the insect's range through the Cumberland Plateau region is assured by an abundance of several oak (*Quercus*) species, which are the preferred host plants (Liebhold et al. 1995). Natural resource managers and land owners must make decisions regarding management approaches for invading gypsy moth populations, while minimizing the effects on non-target organisms due to management tactics.

The most common management tactic for gypsy moth suppression is applications of *Bacillus thuringiensis* variety *kurstaki* (*Btk*), a lepidopteran-specific spore-forming bacterium that produces a toxin, disrupting the epithelial layer of the insect midgut. The risks to non-target organisms due to *Btk* applications are highest for early-season susceptible lepidopterans present during the application window (Hall et al. 1999; James et al. 1993). Direct non-target risks are much lower for non-lepidopterans and for those present beyond the treatment window (Reardon et al. 1994). An additional option for gypsy moth suppression includes applications of diflubenzuron, a chitin-inhibiting insect growth regulator that, when applied at reduced rates, disrupts gypsy moth cuticle formation during molting. Because it targets the chitinous protein component of invertebrate exoskeletons (Grosscourt and Jongsma 1987), the risks to non-target organisms associated with diflubenzuron applications are considerably greater. Finally, managers may opt for a hands-off approach where defoliation by the gypsy moth is allowed to run its course (Liebhold and McManus 1999), which also has risks associated with competitive displacement of non-target organisms and shifts in forest stand composition (Fajvan and Wood 1996).

This study assessed the impact of these management strategies on non-target forest arthropod abundance prior to gypsy moth establishment in the region. The effects of treatments on forest arthropod abundance were evaluated in the year of application and one year post-application. In previous work we reported the effects of our treatments on soil and litter arthropods (Rieske and Buss 2001a). Here we focus on stem-dwelling arthropods.

[1] Current address: 2600 S.W. Williston Rd. #1921, Gainesville, Florida 32608.

MATERIALS AND METHODS

We established research blocks in early spring 1997 in southeastern Kentucky (University of Kentucky Robinson Forest, Breathitt and Knott Counties, and Kentucky Ridge State Forest, Bell Co.). At Robinson Forest the terrain consisted of deeply dissected drainages with steep hillsides. Although blocks were comparable with respect to species composition, stand age, and stocking density, they varied in slope and aspect and ranged in elevation from 325 to 475 m. Kentucky Ridge State Forest is located on Pine Mountain, a single mountain 40 km wide and 201 km in length, where slope, aspect, and elevation were more consistent (18–30°, south-southeast, 550–625 m); thus, our sample block was less variable. At both sites the overstory and mid-story species composition was predominantly oaks and maples (*Acer* spp.) with the understory and herbaceous components dominated by mountain laurel (*Kalmia latifolia* L.), and greenbrier (*Smilax rotundifolia* L.).

A fixed-wing aircraft was used for a single application of: (1) diflubenzuron (Dimilin® 25W, Uniroyal Chemical Company, Middlebury, CT) applied at the rate of 70 g ai/ha, and (2) *Btk* (Dipel® 4L, Abbott Laboratories, North Chicago, IL), applied at the label rate of 2.3 L/ha. Untreated plots were not sprayed. Treatments were applied on 7 May 1997, corresponding to 2 wk following hatch of sentry gypsy moth eggs (Rieske and Buss 2001a), when the majority of larvae were in the second instar and white oak (*Quercus alba* L.) leaf expansion was 25–30%. At the time of application, the air temperature was ca. 21°C with overcast skies and a wind speed of less than 8 km/hr. Spray cards placed in the understory within each plot 1–2 m above ground level were used to confirm coverage.

At Robinson Forest, three 13-ha plots (ca. 213 × 610 m) were established in each of three blocks in a complete randomized block design. At Kentucky Ridge State Forest, only one block containing three 13-ha plots was sampled. A transect was established within each plot ca. 203 m from one end and an arthropod sampling station was positioned at the center of the transect. There was one sample station per plot; nine at Robinson Forest and three at Kentucky Ridge State Forest, for a total of 12 sample stations. At both sites, plots were surrounded by buffer strips of 100 m, which were not treated and not sampled.

Table 1. Habitat variables measured from a 6 m × 6 m area at each sample station (n = 24) used in principal components analysis for assessment of arthropod abundance in two southeastern Kentucky forests, 1997 and 1998.

Variable	Description
RCOV	Rock cover (%)
LCOV	Litter cover (%)
LDEP	Litter depth (cm)
CWD	Coarse woody debris (%) (debris ≥6 cm diameter)
HCOV	Herbaceous cover (%) (nonwoody plants)
SHRCOV	Shrub cover (%) (woody plants <3 m tall)
CC1	Canopy cover between 3.0 and 5.9 m (%)
CC2	Canopy cover between 6.0 and 11.9 m (%)
CC3	Canopy cover greater than 12.0 m (%)
DECOV	Deciduous canopy cover (%)
CONCOV	Coniferous canopy cover (%)
TOTCOV	Total canopy cover (%)

In addition to slope and aspect, we measured habitat variables (Table 1) a single time in a 6 × 6 m area, using the transect center as the center of the assessment area, to characterize habitat variability (Martinat et al. 1993; Rieske and Buss 2001a, 2001b). Daily precipitation and maximum and minimum temperatures were obtained from a weather station located at the University of Kentucky Robinson Forest Camp Headquarters, ca. 3.9–5.4 km from the Robinson Forest plots. No weather data were available for our Kentucky Ridge site.

We used funnel traps and stem traps located at one sample station in each plot to sample stem-dwelling arthropods over the 2-yr period. Funnel trap sampling began on 7 May 1997, concurrent with treatment applications. Stem trap sampling began 14 d later. We monitored plots at 14 d intervals through July and at 30 d intervals thereafter through October. In 1998, we sampled funnel traps and stem traps at 14 d intervals from 15 April through July and at 30 d intervals thereafter.

Lindgren 12-funnel traps (Pherotec Inc., Vancouver, BC, Canada), designed specifically for monitoring coleopterans, were used to sample arthropods throughout the 1997 and 1998 seasons. We baited the funnel traps with 95% ethanol dispensed from a 6 dram vial suspended from the second funnel. Ethanol was

chosen because it is a product of plant fermentation attractive to a variety of insects (Borror et al. 1989; Champlain and Knull 1932; Montgomery and Wargo 1983). Traps were suspended from oak trees 3 m above ground level and Dichlorvos fumigant strips (Roxide International, New Rochelle, NY) were used as the killing agent. Insects were removed from the holding cups at each sample interval and stored in 70% ethanol prior to counting and identifying.

To further sample stem-dwelling arthropods that did not respond to the funnel traps, we developed stem traps consisting of 10 cm diameter aluminum troughs attached to the bole of oak trees ca. 125 cm above ground level and placed >10 m from the funnel trap. A pyrethroid insecticide (Ammo® 2.5 EC, FMC Corp., Philadelphia, PA) was applied to runoff in the trough and to the bole of the tree 1 m above the trough. Arthropods landing on the tree bole succumbed to the insecticide and dropped into the trough. The insecticide was reapplied and samples were collected at each monitoring interval and stored in 70% ethanol prior to sorting and identifying. All insects greater than 6.4 mm collected from each trap type were identified to order and family using available guides and keys (Borror et al. 1989; White 1983).

Data from each trap type were analyzed using a complete randomized block design with blocking by location (plot) within the Robinson Forest and Kentucky Ridge sites. A mixed model analysis of variance (PROC MIXED, SAS Institute 1997) was used to assess differences in arthropod abundance based on gypsy moth suppression tactic and on location (plot).

We also applied principal components analysis to the 12 habitat variables listed in Table 1 to minimize the effects of habitat variability on our measures of abundance. We included the first five principal component scores because their Eigenvalues were greater than 1 and then used the scores as covariates in the treatment effects model. Collectively these five principal components take into account >80% of the variability in our sample plots. If the scores generated by the principal components analyses failed to explain arthropod distribution patterns based on habitat variability, we instead report results from the simpler block analysis.

For each trap type, the dependent variables tested were the total number of individuals of each of the major taxa represented in each sampling interval and across all sampling intervals within each year. Significant treatment differences were analyzed using Fisher's LSD test.

RESULTS

Weather conditions differed significantly between the treatment and post-treatment years, with warmer and wetter conditions in 1998. Mean daily temperatures were different between years ($|t|_{1,321} = 5.72$, $P < 0.0001$), with 1998 experiencing warmer temperatures in the winter (December through February, 1997: 3.6°C, 1998: 4.8°C, $|t|_{1,73} = 2.19$, $P = 0.03$), summer (June through August, 1997: 22.0°C, 1998: 22.9°C, $|t|_{1,85} = 2.58$, $P = 0.01$), and fall (September through November, 1997: 12.3°C, 1998: 15.9°C, $|t|_{1,82} = 9.48$, $P < 0.0001$) seasons. Overall precipitation also was significantly different between years (1997: 102.2 cm, 1998: 128.6 cm, $|t|_{1,364} = 2.16$, $P = 0.03$) due to the wetter summer months of 1998 (1997: 0.25 cm, 1998: 0.42 cm, $|t|_{1,91} = 2.12$, $P = 0.04$).

There were no significant differences in the abundance of any taxon in funnel trap samples based on the gypsy moth suppression tactics we applied (Table 2). Funnel trap contents in 1997 consisted primarily of beetles, capturing 5513 coleopterans in eight families (Table 2). Bark/ambrosia beetles were most abundant (61%), followed by rove beetles (12%), carrion beetles (11%), click beetles (8%), and weevils (5%). Less frequently captured families included long-horned beetles (2%), false click beetles (1%), and metallic wood-boring beetles (0.2%). In 1998, coleopterans in funnel traps were less abundant (3058 individuals) but more diverse, with eleven families comprising 82% of the total (Table 2). Bark/ambrosia beetles were again most abundant (32%), followed by carrion beetles (12%), rove beetles (9%), and click beetles (8%). The remaining seven families each comprised <5% of the total (comb-clawed beetles [2%], ground beetles [4%], weevils [2%], minute brown scavenger beetles [3%], small carrion beetles [4%], ptilodactylid beetles [2%], and scarab beetles [4%]).

Sample date significantly affected the abun-

Table 2. Abundance of arthropods,mean (±SE), comprising >5% of the total in funnel traps in 1997 and 1998 from deciduous forests in southeastern Kentucky treated with a May 1997 application of *Btk* and diflubenzuron.

	% total	*Btk*	Diflubenzuron	Untreated control	F_{df}/Pr > F
		1997			
Curculionidae (weevils)	5	4.11 (0.82)	3.18 (0.70)	2.57 (0.54)	$F_{2,3}$ = 2.17/0.13
Elateridae (click beetles)	8	5.25 (0.67)	4.61 (0.69)	5.07 (0.68)	$F_{2,7}$ = 0.80/0.25
Scolytidae (bark/ambrosia beetles)	61	42.18 (6.84)	33.93 (4.94)	44.54 (7.22)	$F_{2,5}$ = 0.61/0.29
Silphidae (carrion beetles)	11	11.50 (7.60)	5.00 (3.66)	4.46 (3.82)	$F_{2,7}$ = 0.64/0.28
Staphylinidae (rove beetles)	12	8.61 (1.35)	8.61 (1.67)	6.54 (0.86)	$F_{2,8}$ = 0.61/0.29
Total	97	73.39 (9.52)	57.25 (8.15)	66.25 (8.48)	$F_{2,5}$ = 0.07/0.47
		1998			
Curculionidae (weevils)	2	1.60 (0.48)	1.88 (0.81)	1.00 (0.41)	$F_{2,5}$ = 1.59/0.15
Elateridae (Click beetles)	8	5.93 (1.67)	5.75 (1.14)	4.31 (0.95)	$F_{2,5}$ = 0.01/0.50
Scolytidae (bark/ambrosia beetles)	32	20.73 (5.49)	21.44 (6.16)	22.94 (4.68)	$F_{2,7}$ = 0.11/0.45
Silphidae (carrion beetles)	12	15.47 (13.84)	8.38 (8.31)	0.06 (0.06)	$F_{2,5}$ = 2.23/0.11
Staphylinidae (rove beetles)	9	8.00 (2.70)	4.94 (1.22)	4.31 (0.88)	$F_{2,5}$ = 2.28/0.10
Total	63	74.44 (21.01)	64.44 (13.98)	52.25 (6.43)	$F_{2,5}$ = 2.68/0.08

dance of several beetle families in our funnel traps (Figure 1). Bark/ambrosia beetle abundance progressively declined in 1997 (Figure 1a), as did the abundance of rove beetles (Figure 1c) and weevils (Figure 1i), but abundance of these taxa was unaffected by sample interval in 1998 (Figure 1b, d, and j, respectively). Carrion beetle (Figure 1e) and click beetle (Figure 1g) abundance were not affected by date in 1997, but were affected by sample date in 1998 (Figure 1f and h, respectively).

The abundance of bark/ambrosia beetles, the most prevalent taxon in both years, was significantly explained by the plot analysis in both 1997 ($F_{3,9}$ = 8.26; P = 0.006) and 1998 ($F_{3,6}$ = 23.02; P = 0.0009) with funnel traps in Kentucky Ridge State Forest capturing greater numbers of bark/ambrosia beetles than funnel traps in Robinson Forest in 1997. In spite of the differences in abundance based on site, our treatment applications still had no significant impact on scolytid abundance.

Rove beetle spatial abundance was not significantly explained by either the plot analysis or the principal components analysis in 1997. However, in 1998, the principal components analysis was significant in explaining rove beetle abundance ($F_{1,30}$ = 9.98; P = 0.004), which was positively correlated with mid-canopy cover and litter depth and negatively correlated with upper canopy cover and percent litter cover. This accounted for >20% of the variability between plots.

The plot analysis and the principal components analysis failed to explain carrion beetle spatial abundance in 1997 funnel traps. In 1998, the principal component of significance ($F_{1,30}$ = 14.84; P = 0.0006) again was positively correlated with mid-canopy cover and litter depth, and negatively correlated with upper canopy cover and percent litter cover. This again accounted for >20% of the variability between plots. Neither the plot analysis nor the principal components analysis adequately explained click beetle spatial abundance in 1997, but in 1998, plot was a significant factor explaining click beetle abundance ($F_{3,6}$ = 4.61; P = 0.05).

Finally, the principal components analysis was weakly significant in explaining 1997 weevil abundance ($F_{1,4}$ = 6.10; P = 0.06). It was positively associated with lower canopy cover and herbaceous plant cover but negatively associated with coarse woody debris. Neither analysis adequately explained weevil abundance in 1998, when weevil trap catch was only 2% of the total.

Stem traps captured a total of 6116 arthropods in 1997 and 10186 arthropods in 1998. Beetles were the most prevalent taxon captured in stem traps (Table 3) in both years (57% and 72%, respectively). Predatory ground beetles were the most abundant beetle family in 1997, comprising 31% of the beetles captured. The next most abundant were the rove beetles (21%), carrion beetles (16%), weevils (14%), click beetles (8%), and bark/ambrosia beetles (5%). The remaining beetle families comprised <5% of the total. In 1998, ground beetles were again the most abundant

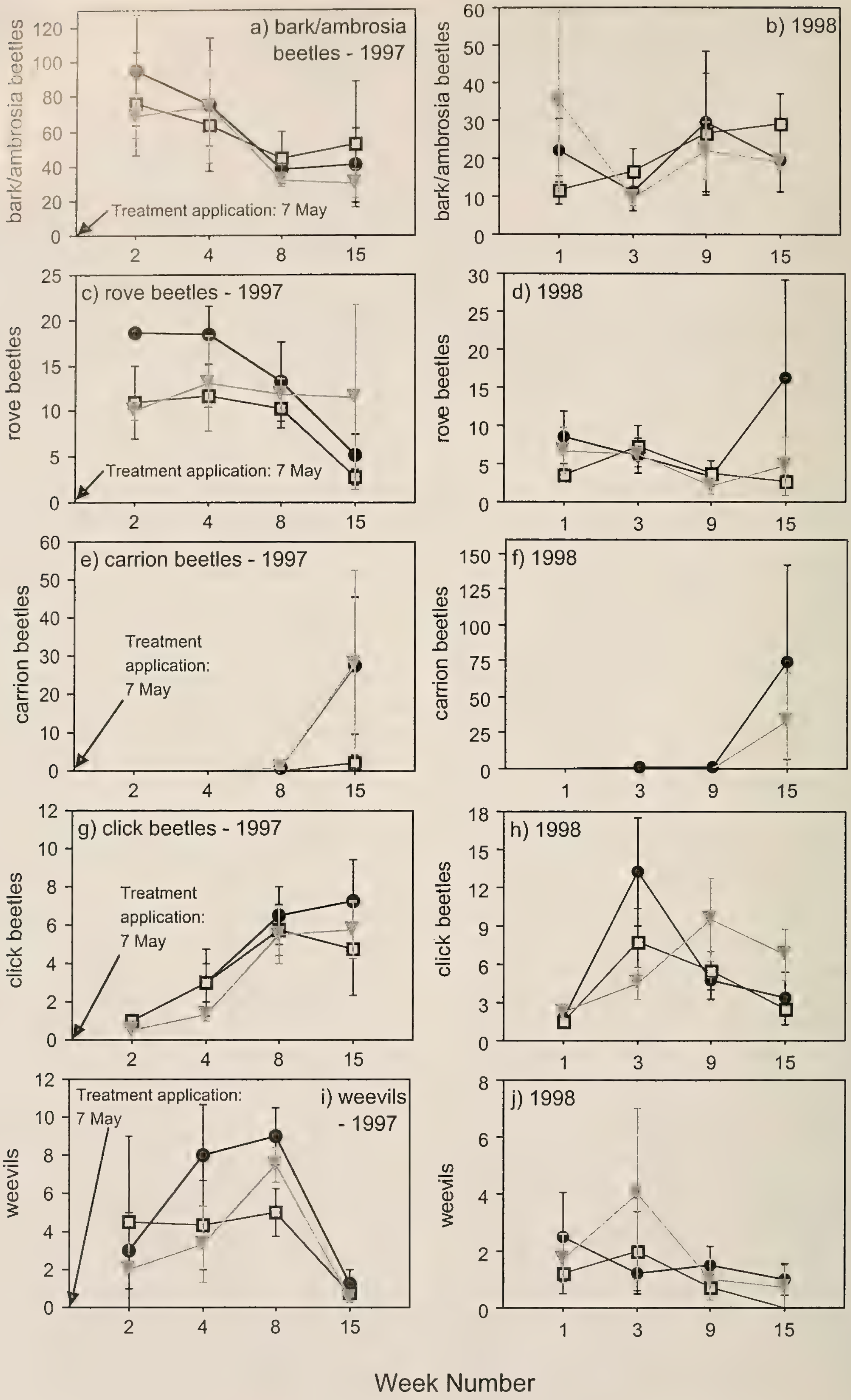

a) bark/ambrosia beetles - 1997
b) 1998
bark/ambrosia beetles
Treatment application: 7 May
c) rove beetles - 1997
d) 1998
rove beetles
e) carrion beetles - 1997
f) 1998
carrion beetles
g) click beetles - 1997
h) 1998
click beetles
i) weevils - 1997
j) 1998
weevils
Week Number

Table 3. Abundance of arthropods, mean (±SE), comprising >5% of the total in stem traps in 1997 and 1998 from deciduous forests in southeastern Kentucky treated with a May 1997 application of *Btk* and diflubenzuron.

	% total	*Btk*	Diflubenzuron	Untreated control	F_{df}/Pr > F
		1997			
Ants (Hymenoptera)	24	16.16 (4.10)	25.65 (5.98)	15.35 (3.47)	$F_{2,8}$ = 0.18/0.42
Beetles (Coleoptera)	57	44.23 (4.80)	35.04 (3.61)	54.85 (5.83)	$F_{2,6}$ = 1.45/0.15
Carabidae (ground beetles)	% beetles 31	16.70 (3.18)	8.58 (1.61)	17.23 (2.49)	$F_{2,8}$ = 2.06/0.10
Curculionidae (weevils)	14	5.40 (1.37)	6.42 (1.15)	8.42 (1.84)	$F_{2,7}$ = 2.65/0.07
Elateridae (click beetles)	8	3.64 (0.49)	4.58 (1.56)	3.23 (0.56)	$F_{2,3}$ = 1.59/0.17
Scolytidae (bark/ambrosia beetles)	5	1.60 (0.53)[1]	2.23 (0.81)	4.04 (1.54)	$F_{2,8}$ = 4.93/0.02
Silphidae (carrion beetles)	16	7.52 (2.70)	5.27 (1.65)	9.58 (2.33)	$F_{2,3}$ = 3.66/0.07
Staphylinidae (rove beetles)	21	9.40 (1.45)	7.23 (1.63)	12.42 (1.78)	$F_{2,8}$ = 0.51/0.31
Millipedes (Diplopoda)	6	0.60 (0.27)	0.15 (0.07)	0.85 (0.26)	$F_{2,3}$ = 2.11/0.13
Spiders (Araneae)	13	11.24 (1.66)	10.23 (0.89)	11.35 (1.39)	$F_{2,7}$ = 0.52/0.31
		1998			
Ants (Hymenoptera)	14	14.25 (4.64)	15.75 (4.00)	9.25 (2.25)	$F_{2,6}$ = 3.50/0.06
Beetles (Coleoptera)	72	69.31 (11.28)	52.69 (5.89)	78.56 (10.98)	$F_{2,4}$ = 2.01/0.13
Carabidae (ground beetles)	% beetles 36	28.56 (4.93)	13.50 (2.63)	29.75 (5.11)	$F_{2,4}$ = 1.36/0.18
Curculionidae (weevils)	2	9.63 (2.10)	10.13 (1.40)	10.25 (1.52)	$F_{2,4}$ = 1.95/0.13
Elateridae (click beetles)	4	2.94 (0.66)	2.00 (0.47)	3.94 (0.92)	$F_{2,4}$ = 2.06/0.12
Scolytidae (bark/ambrosia beetles)	4	1.88 (0.52)	2.19 (0.49)	3.94 (0.80)	$F_{2,4}$ = 0.73/0.27
Silphidae (carrion beetles)	1	0.44 (0.27)	0.63 (0.22)	1.25 (0.65)	$F_{2,4}$ = 3.06/0.08
Staphylinidae (rove beetles)	11	7.38 (2.49)	6.50 (1.53)	8.69 (2.74)	$F_{2,4}$ = 3.16/0.08
Millipedes (Diplopoda)	<1	0.25 (0.19)	0.63 (0.22)	0.56 (0.20)	$F_{2,4}$ = 1.43/0.17
Spiders (Araneae)	12	10.50 (2.15)	10.19 (1.53)	12.56 (2.37)	$F_{2,4}$ = 4.01/0.06

[1] Significant difference from untreated control, but not from diflubenzuron.

(36%) followed by rove beetles (11%). Click beetles and bark/ambrosia beetles comprised 4% of the total, weevils comprised 2% and carrion beetles comprised only 1%.

Ants (Hymenoptera: Formicidae) were the next most prominent taxon, comprising 24% and 14% of the stem trap totals in 1997 and 1998, respectively. Spiders (Araneae) comprised 13% of the total in 1997 and 12% of the total in 1998. Lastly, millipedes (Diplopoda) represented 6% of the stem trap total in 1997 but <1% in 1998.

Bark/ambrosia beetles captured in 1997 stem traps were the only group affected by our treatment applications ($F_{2,9}$ = 4.93, P = 0.02) and were more abundant in untreated control plots than in *Btk*-treated plots (Table 3).

Sample date significantly affected the abundance of several taxa in stem traps (Figure 2). In 1997, ant abundance declined due primarily to initially high numbers in the diflubenzuron-treated plots (Figure 2a). Sample date also was a significant factor in 1998, when ant abundance in stem traps increased gradually as the season progressed (Figure 2b). Total beetle abundance in 1997 also was significantly impacted by sample date, due primarily to a decrease in stem trap catch in control plots during week 12 (Figure 2c). In 1998, sample interval was not a significant factor explaining total beetle abundance in stem traps (Figure 2d). Millipedes declined seasonally in 1997 (Figure 2e), but not in 1998 (Figure 2f). Spiders also declined seasonally in 1997 (Figure 2g). Sample date also impacted spider num-

←

Figure 1. Seasonal abundance of various taxa collected in funnel traps from forest plots in Kentucky treated in May 1997 with three gypsy moth management tactics (—●— *Btk*; —▼— diflubenzuron; —□— untreated control). Bark/ambrosia beetles in a) 1997 ($F_{7,50}$ = 71.20, P < 0.0001) and b) 1998 (no significant difference), rove beetles in c) 1997 ($F_{7,53}$ = 4.36, P < 0.0007) and d) 1998 (no significant difference), carrion beetles in e) 1997 (no significant difference) and f) 1998 ($F_{3,24}$ = 4.72, P = 0.01), click beetles in g) 1997 (no significant difference) and h) 1998 ($F_{3,30}$ = 5.98, P = 0.003), and weevils in i) 1997 ($F_{7,51}$ = 2.77, P < 0.02) and j) 1998 (no significant difference).

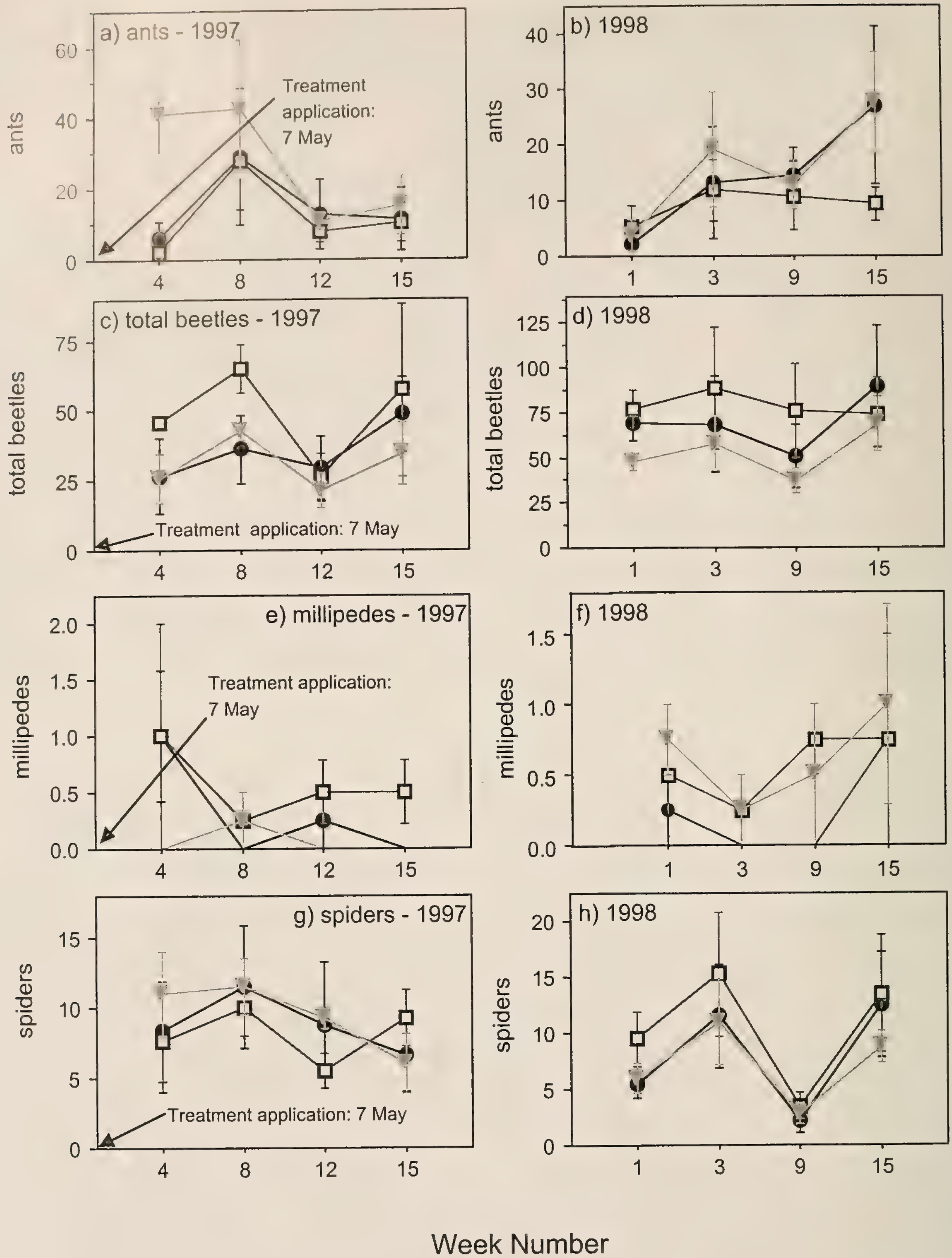


Figure 2. Seasonal abundance of various taxa collected in stem traps from forest plots in Kentucky treated in May 1997 with three gypsy moth management tactics (—●— *Btk*; —▼— diflubenzuron; —□— untreated control). Ants in a) 1997 ($F_{5,36}$ = 2.72, P = 0.03) and b) 1998 ($F_{3,27}$ = 5.59, P = 0.004), total beetles in c) 1997 ($F_{5,32}$ = 7.28, P = 0.0001) and d) 1998 (no significant difference), millipedes in e) 1997 ($F_{5,33}$ = 3.61, P = 0.01) and f) 1998 (no significant difference), and spiders in g) 1997 ($F_{5,30}$ = 17.71, P < 0.0001) and h) 1998 ($F_{3,27}$ = 10.18, P = 0.0001).

bers in 1998, due to a drastic decline in stem trap catch in all plots during week 9 (Figure 2h).

The abundance of total beetles was explained by the principal components analysis in 1997 ($F_{1,37}$ = 6.24, P = 0.02), with 8% of the variability in total beetle abundance positively correlated with deciduous canopy cover and rock cover but negatively correlated with lower canopy cover. Neither the plot analysis nor the principal components analysis explained total beetle abundance in 1998.

The abundance of ground beetles, the most prevalent beetle family represented in stem traps in both years, was adequately explained by several of the principal components generated from the habitat variables we measured. The principal component accounting for the greatest variability in ground beetle numbers between plots (26%, $F_{1,38}$ = 4.56, P = 0.04) was positively correlated with herbaceous ground cover, litter cover and upper canopy cover but negatively correlated with mid-canopy cover and litter depth. An additional 11% of the variability in ground beetle abundance could be attributed to a principal component that was strongly correlated with herbaceous ground cover and negatively correlated with coarse woody debris ($F_{1,39}$ = 4.59, P = 0.04). Neither the plot analysis nor the principal components analysis adequately explained ground beetle abundance in stem traps in 1998.

The plot analysis and the principal components analysis failed to explain the abundance of rove beetles in stem traps in 1997. In 1998, the principal component of significance ($F_{1,4}$ = 7.63; P = 0.05) was strongly correlated with rock cover and deciduous canopy cover but explained only 8% of the variability.

Again, the plot analysis and the principal components analysis failed to explain carrion beetle spatial abundance in 1997. In 1998, the significant principal component ($F_{1,4}$ = 8.35; P = 0.04) again was positively correlated with rock cover and deciduous cover, negatively correlated with lower canopy cover, and accounted for only 8% of the variability between plots.

Over 20% of the variability in 1997 weevil abundance was significantly and positively correlated with litter cover, coarse woody debris, upper canopy cover, and coniferous canopy cover ($F_{1,37}$ = 5.85, P = 0.02). Similarly, an additional principal component accounted for 17% of the variability in weevil abundance and was positively correlated with herbaceous and lower canopy cover but negatively correlated with litter depth ($F_{1,12}$ = 7.97, P = 0.02). Neither the plot analysis nor the principal components analysis explained weevil abundance in 1998.

Click beetle abundance in stem traps could not be explained by the plot analysis or the principal components analysis in either year.

The spatial abundance of bark/ambrosia beetles in 1997 was significantly and positively correlated with rock cover and deciduous canopy cover but negatively correlated with lower canopy cover ($F_{1,13}$ = 5.28, P = 0.04). Those factors accounted for only 8% of the scolytidae stem trap catch. The plot analysis and principal components analysis could not explain spatial abundance in 1998.

The spatial abundance of ants, the next most prominent taxon in stem traps, was significantly explained by the plot analysis in both 1997 ($F_{3,4}$ = 24.49, P = 0.003) and 1998 ($F_{3,6}$ = 27.35, P = 0.0007).

Millipede abundance in stem traps was positively correlated with herbaceous ground cover and mid-canopy cover in 1997 ($F_{1,6}$ = 14.23, P = 0.01), but these factors accounted for only 7% of the variability in abundance. Spatial abundance of millipedes in 1998 could not be explained by our methods.

Finally, spider abundance in 1997 stem traps was significantly and positively correlated with rock cover, coarse woody debris, and lower canopy cover but negatively correlated with shrub cover ($F_{1,34}$ = 6.24, P = 0.02). These factors explained over 16% of the variability in abundance. In 1998, the principal component positively correlated with litter cover and shrub cover explained nearly 25% of the variability in spider spatial abundance ($F_{1,4}$ = 8.84, P = 0.04).

DISCUSSION

Our results indicate that a single application of diflubenzuron and *Btk* for gypsy moth suppression did not significantly impact abundance of non-target stem-dwelling arthropods collected over a 2-yr period with the sampling techniques we used. Applications of both compounds affected only the abundance of bark/

ambrosia beetles captured in stem traps during the year of application but did not impact beetle abundance in funnel trap catches. Moreover, there were no effects on abundance of any taxon one year post-application for either of our sampling approaches.

Diflubenzuron is a non-specific, chitin-inhibiting compound that has the potential to negatively impact an assortment of non-target arthropods in forest systems. Its use effectively suppresses gypsy moth populations but also can reduce abundance and diversity of non-target arthropods in canopy (Butler and Kondo 1993; Butler et al. 1997; Martinat et al. 1988; Sample et al. 1993) and litter communities (Martinat et al. 1993; Rieske and Buss 2001a). In our study, a single application of diflubenzuron negatively impacted only phloem-feeding, stem-dwelling bark/ambrosia beetles relative to untreated controls (Table 3).

The likelihood of detrimental non-target effects from a single application of lepidopteran-specific *Btk* is much lower than for diflubenzuron. *Btk* also effectively suppresses gypsy moth populations. Applications of *Btk* have been shown to decrease the abundance and diversity of non-target organisms in the short term (Johnson et al. 1995; Miller 1990; Sample et al. 1996) but to increase abundance and diversity in longer term studies (Sample et al. 1996; Venables 1990). *Btk* applications also have been shown to enhance the effectiveness of the gypsy moth natural enemy complex (Andreadis et al. 1983; Reardon et al, 1994; Ticehurst et al. 1982; Webb et al. 1989; Weseloh et al. 1983), although this response is not universal (Flexner et al. 1986).

A no-treatment, hands-off approach to gypsy moth management can result in competitive displacement of native herbivores and cause shifts in forest species composition (Fajvan and Wood 1996) thereby impacting stand productivity (Campbell and Sloan 1977; Collins 1961; Davidson et al. 1999) and affecting wildlife distribution patterns (Gottschalk 1993; Smith 1985; Vaughn and Kasbohm 1993).

Effects of our treatments may have been obscured or confounded by spatial and temporal variability in arthropod abundance due to biotic and abiotic factors. Factors such as temperature, humidity, wind speed, site characteristics, and microhabitat may influence arthropod abundance and distribution patterns as well as the effectiveness of the treatment applications. The variability in weather patterns between the two sampling years undoubtedly influenced our results. We also found considerable variability in abundance in each sampling method within each sample interval due, in part, to the limited plot size in our study which could not control for arthropod dispersal. Lastly, the biases associated with our sampling techniques cannot be discounted. Each method is capable of sampling only a small number of taxa actually present (Muirhead-Thompson 1991) and sample composition is a function of arthropod density, activity level, response to specific stimuli, and environmental complexity.

No single principal component generated by the analysis of our habitat variables adequately explained abundance of the various taxa. The principal component factors most commonly associated with abundance were most indicative of habitat complexity and included litter depth, herbaceous ground cover, and percent cover of the various canopy strata (i.e., lower-, mid-, and upper-canopy). Habitat complexity and vertical stratification is often indicative of terrestrial arthropod diversity including that of spiders (Uetz 1975), beetles (Rieske and Buss 2001b), and various phytophages (Lawton 1983).

Data from this study provide much-needed information on forest arthropod abundance and diversity in the Cumberland Plateau region and contribute to the knowledge base characterizing effects of forest pest suppression tactics on deciduous forest systems. These results provide forest resource managers additional tools necessary to make well-informed decisions regarding the impacts of suppressing gypsy moth infestations prior to their establishment in the region.

ACKNOWLEDGMENTS

We thank Aaron Adams, Emily Bremer, John Ghent, Lindsay Gibson, Kevin Holmes, James Hamilton, Jeremy King, Will Marshall, Jennifer Michaelson, Michael Schiffer, Tim Sheehan, Craig Stillwell, Jason Templin, and James Winter for assistance in site establishment, plot monitoring, and sample processing, and Michelle D. Smith and Brian Strom for assistance in statistical analysis. The comments of Ken Yeargan improved this manuscript.

This research was supported by National Agricultural Pesticide Impact Assessment Program Grant R8-33, and McIntire Stennis funds from the Kentucky Agricultural Experiment Station, and is published as Experiment Station Project 01-08-23.

LITERATURE CITED

Andreadis, T. G., N. R. DuBois, R. E. B. Moore, J. F. Anderson, and F. B. Lewis. 1983. Single applications of high concentrations of *Bacillus thuringiensis* for control of gypsy moth (Lepidoptera: Lymantriidae) populations and their impact on parasitism and disease. J. Econ. Entomol. 76:1417–1422.

Borror, D. J., C. A. Triplehorn, and N. F. Johnson. 1989. An introduction to the study of insects, 6th ed. Saunders, Philadelphia, PA.

Butler, L., and V. Kondo. 1993. Impact of diflubenzuron on non-target lepidoptera: results of an operational gypsy moth suppression program at Coopers Rock State Forest, West Virginia. West Virginia Univ. Agric. For. Exp. Sta. Bull. 710.

Butler, L., G. A. Chrislip, V. A. Kondo, and E. C. Townsend. 1997. Effect of diflubenzuron on nontarget canopy arthropods in closed, deciduous watersheds in a central Appalachian forest. J. Econ. Entomol. 90:784–794.

Campbell, R. W., and R.J. Sloan. 1977. Forest stand responses to defoliation by the gypsy moth. For. Sci. Monogr. 19.

Champlain, A. B., and J. N. Knull. 1932. Fermenting baits for trapping Elateridae and Cerambycidae (Coleop.). Entomol. News 43:253–257.

Collins, S. 1961. Benefits to understory from canopy defoliation by gypsy moth larvae. Ecology 42:846–848.

Davidson, C. B., K. W. Gottschalk, and J. E. Johnson. 1999. Tree mortality following defoliation by the European gypsy moth (*Lymantria dispar* L.) in the United States: a review. For. Sci. 45:74–84.

Fajvan, M. A., and J. M. Wood. 1996. Stand structure and development after gypsy moth defoliation in the Appalachian Plateau. For. Ecol. Managem. 89:79–88.

Flexner, J. L., B. Lighthart, and B. A. Croft. 1986. The effects of microbial pesticides on non-target, beneficial arthropods. Agric., Ecosyst. and Environm. 16:203–254.

Gottschalk, K. W. 1993. Gypsy moth effects on mast production. In: C. E. McGee (ed). Proceedings, Southern Appalachian mast management workshop, August 14–16, 1986. Univ. Tennessee, Knoxville.

Grosscourt, A. C., and B. Jongsma. 1987. Mode of action and insecticidal properties of diflubenzuron. Pages 75–99 in J. E. Wright, and A. Retnakaran (eds). Benzoylphenyl ureas. Plenum, New York, NY.

Hall, S. P., J. B. Sullivan, and D. F. Schweitzer. 1999. Assessment of risk to non-target macro-moths after *Bacillus thuringiensis* var. *kurstaki* application to Asian gypsy moth in the Cape Fear region of North Carolina. U.S.D.A. For. Serv. FHTET-98-16, Morgantown, WV.

James, R. R., J. C. Miller, and B. Lighthart. 1993. *Bacillus thuringiensis* var. *kurstaki* affects a beneficial insect, the cinnabar moth (Lepidoptera: Arctiidae). J. Econ. Entomol. 86:334–339.

Johnson, K. S., M. Scriber, J. K. Nitao, and D. R. Smitely. 1995. Toxicity of *Bacillus thuringiensis* var. *kurstaki* to three nontarget Lepidoptera in field studies. Environm. Entomol. 24:288–297.

Lawton, J. H. 1983. Plant architecture and the diversity of phytophagous insects. Ann. Rev. Entomol. 28:23–39.

Liebhold, A. M., K. W. Gottschalk, R. M. Muzika, M. E. Montgomery, R. Young, K. O'Day, and B. Kelley. 1995. Suitability of North American tree species to gypsy moth: a summary of field and laboratory tests. U.S.D.A. For. Serv., Northeast. Forest Exp. Sta. Gen. Techn. Rep. NE-211. Radnor, PA.

Liebhold, A. M., and M. McManus. 1999. The evolving use of insecticides in gypsy moth management. J. For. 97:20–24.

Martinat, P. J., C. C. Coffman, K. Dodge, R. J. Cooper, and R. C. Whitmore. 1988. Effect of diflubenzuron on the canopy arthropod community in a central Appalachian forest. J. Econ. Entomol. 81:261–267.

Martinat, P. J., D. T. Jennings, and R. C. Whitmore. 1993. Effects of diflubenzuron on the litter spider and orthopteroid community in a central Appalachian forest infested with gypsy moth (Lepidoptera: Lymantriidae). Environm. Entomol. 22:1003–1008.

Miller, J. C. 1990. Field assessment of the effects of a microbial pest control agent on nontarget Lepidoptera. Am. Entomol. 40:135–139.

Montgomery, M. E., and P. M. Wargo. 1983. Ethanol and other host-derived volatiles as attractants to beetles that bore into hardwoods. J. Chem. Ecol. 9:181–190.

Muirhead-Thomson, R.C. 1991. Trap responses of flying insects. Academic Press, San Diego, CA.

Reardon, R., N. Dubois, and W. McLane. 1994. *Bacillus thuringiensis* for managing gypsy moth: a review. U.S.D.A. For. Serv. Natl. Center of Forest Health Managem. Techn. Transfer FHM-NC-01-94.

Rieske, L. K., and L. J. Buss. 2001a. Effects of gypsy moth suppression tactics on litter- and ground-dwelling arthropods in the central hardwood forests of the Cumberland Plateau. For. Ecol. Managem. 149:181–195.

Rieske, L. K., and L. J. Buss. 2001b. Influence of site on diversity and abundance of ground- and litter-dwelling Coleoptera in Appalachian oak-hickory forests. Environ. Entomol. 30:484–494.

Sample, B. E., L. Butler, and R. C. Whitmore. 1993. Effects of an operational application of Dimilin® on nontarget insects. Canad. Entomol. 125:173–179.

Sample, B. E., L. Butler, C. Zivkovich, R. C. Whitmore, and R. Reardon. 1996. Effects of *Bacillus thuringiensis* Berliner var. *kurstaki* and defoliation by the gypsy moth [*Lymantria dispar* (L.) (Lepidoptera: Lymantriidae)] on

native arthropods in West Virginia. Canad. Entomol. 128:573–392.

SAS Institute. 1997. SAS/STAT software: changes and enhancements through release 6.12. SAS Institute, Cary, NC.

Smith, H. R. 1985. Wildlife and the gypsy moth. Wildlife Soc. Bull. 13:166–174.

Ticehurst, M., R. A. Fusco, and E. M. Blumenthal. 1982. Effects of reduced rates of Dipel 4L, Cylox 1.5 oil, and Dimilin W-25 on *Lymantria dispar* (L.) (Lepidoptera: Lymantriidae), parasitism, and defoliation. Environm. Entomol. 11:1058–1062.

Uetz, G. W. 1975. Temporal and spatial variation in species diversity of wandering spiders (Araneae) in deciduous forest litter. Environm. Entomol. 4:719–724.

Vaughn, M. R., and J. W. Kasbohm. 1993. Response of black bears to gypsy moth infestation in Shenandoah National Park, Virginia. Page 111 in S. L. C. Fosbroke and K. W. Gottschalk (eds). Proceedings, U.S.D.A. Interagency Gypsy Moth Research Forum. General Techn. Rep. NE-179: 111.

Venables, B. A. B. 1990. Preliminary assessment of the susceptibilities of non-target lepidopteran species to *Bacillus thuringiensis* (*B.t.*) and Dimilin used for gypsy moth suppression. Report to the U.S.D.I., Natl. Park Serv., Natl. Capital Region.

Webb, R. E., M. Shapiro, J. D. Podgwaite, R. C. Reardon, K. M. Tatman, L. Venables, and D. M. Kolodny-Hirsch. 1989. Effect of aerial spraying with dimilin, dipel, or gypchek on two natural enemies of the gypsy moth (Lepidoptera: Lymantriidae). J. Econ. Entomol. 82: 1695–1701.

Weseloh, R. M., T. G. Andreadis, R. E. B. Moore, J. F. Anderson, N. R. DuBois, and F. B. Lewis. 1983. Field confirmation of a mechanism causing synergism between *Bacillus thuringiensis* and the gypsy moth parasitoid, *Apanteles melanoscelus*. J. Invert. Pathol. 41:99–103.

White, R. E. 1983. A field guide to the beetles of North America. Houghton Mifflin Co., Boston, MA.

J. Ky. Acad. Sci. 63(1):19–38. 2002.

Notes on North American *Elymus* Species (Poaceae) with Paired Spikelets. II. The *interruptus* Group

Julian J. N. Campbell

The Nature Conservancy (Kentucky Chapter), 642 W Main Street, Lexington, Kentucky 40508

ABSTRACT

Taxonomic problems in *Elymus interruptus* Buckley and allied species are addressed and a synthesis of relevant observations is presented. Updated descriptions are provided for *E. interruptus* (sensu stricto) from the southwestern United States and northern Mexico, *E. pringlei* Scribn. & Merr. from eastern Mexico, and *E. svensonii* G.L. Church from Tennessee and Kentucky. Also, provisional new descriptions are provided for *pringlei*-like plants from the Edwards Plateau in Texas, and for *svensonii*-like plants from the Ouachita and Ozark mountains in Arkansas, Missouri, and Oklahoma. The hypothesis is advanced that several taxa in the *interruptus* group have originated from independent hybridizations between *E. canadensis* and *E. hystrix* or related species.

INTRODUCTION

This paper is the second in a series that addresses taxonomic problems among North American *Elymus* species with paired spikelets. The first dealt with taxa related to *E. virginicus* L. and *E. glaucus* Buckley (Campbell 2000). In another problematic section of the genus, several populations of *Elymus* in eastern and central North America appear intermediate in morphology and habitat between *E. canadensis* L., a widespread variable species centered in the Great Plains Grasslands, and *E. hystrix* L., a species of the Eastern Deciduous Forests. *Elymus interruptus* Buckley (1862) was the first of these to be described as a distinct species, which became reported from Texas to Minnesota in Hitchcock (1935; Hitchcock and Chase 1951) and several other contemporary manuals (e.g., Fernald 1950).

Later, largely due to the work of Church (1954, 1958, 1967), it became clear that Hitchcock had included at least three distinct entities in his concept of *Elymus interruptus*. Church (1967) reduced *E. interruptus* to a variety of *E. canadensis,* known only from southern regions in Texas, New Mexico, Arizona, and Coahuila. He reapplied the name *E. diversiglumis* Scribn. & C.R. Ball (1901) to plants of the northern Great Plains and described *E. svensonii* G.L. Church from bluffs of the Cumberland River system in Tennessee. Max E. Medley and I subsequently discovered *E. svensonii* along bluffs of the Kentucky River in Kentucky (Medley 1993). As affirmed in this paper, current data indicate that these three taxa have disjunct ranges (Figure 1).

Church (1967) hypothesized that these three taxa originated from independent hybridizations between *Elymus canadensis* and *E. hystrix* or related species. While they all have curving awns and other general similarities to *E. canadensis,* their glumes are reduced to various degrees and appear transitional to *E. hystrix,* which typically has only vestigial glumes up to ca. 1 mm long. Church also showed that artificial hybrids between various races of *E. canadensis* and *E. hystrix* have much similarity to the three supposedly derived taxa.

Existing knowledge of natural hybrids between the above taxa and *Elymus canadensis* or *E. hystrix* may be summarized as follows, based on Church's (1954, 1958, 1967) work and my examination of specimens at the following herbaria: GH, ISC, KANU, KY, MADI, MO, NCU, OKL, SMU, TEX, UARK, US, UTC, VDB, WIS (Holmgren et al. 1990).

(1) Within the relatively large range of *E. diversiglumis* (Figure 1), collections and field observations provide several cases of apparent introgression among populations of *E. canadensis* var. *canadensis, E. diversiglumis* and *E. hystrix.*

(2) Within the small range of typical *E. svensonii* (Figure 1), there is much introgression between that species and *E. hystrix* (as supported by collections of D. White et al. at Kentucky State Nature Preserves Commission and KY). The closest known stations of *E. canadensis* are 50–100 miles further west or north (Figure 2). However, it is possible that there

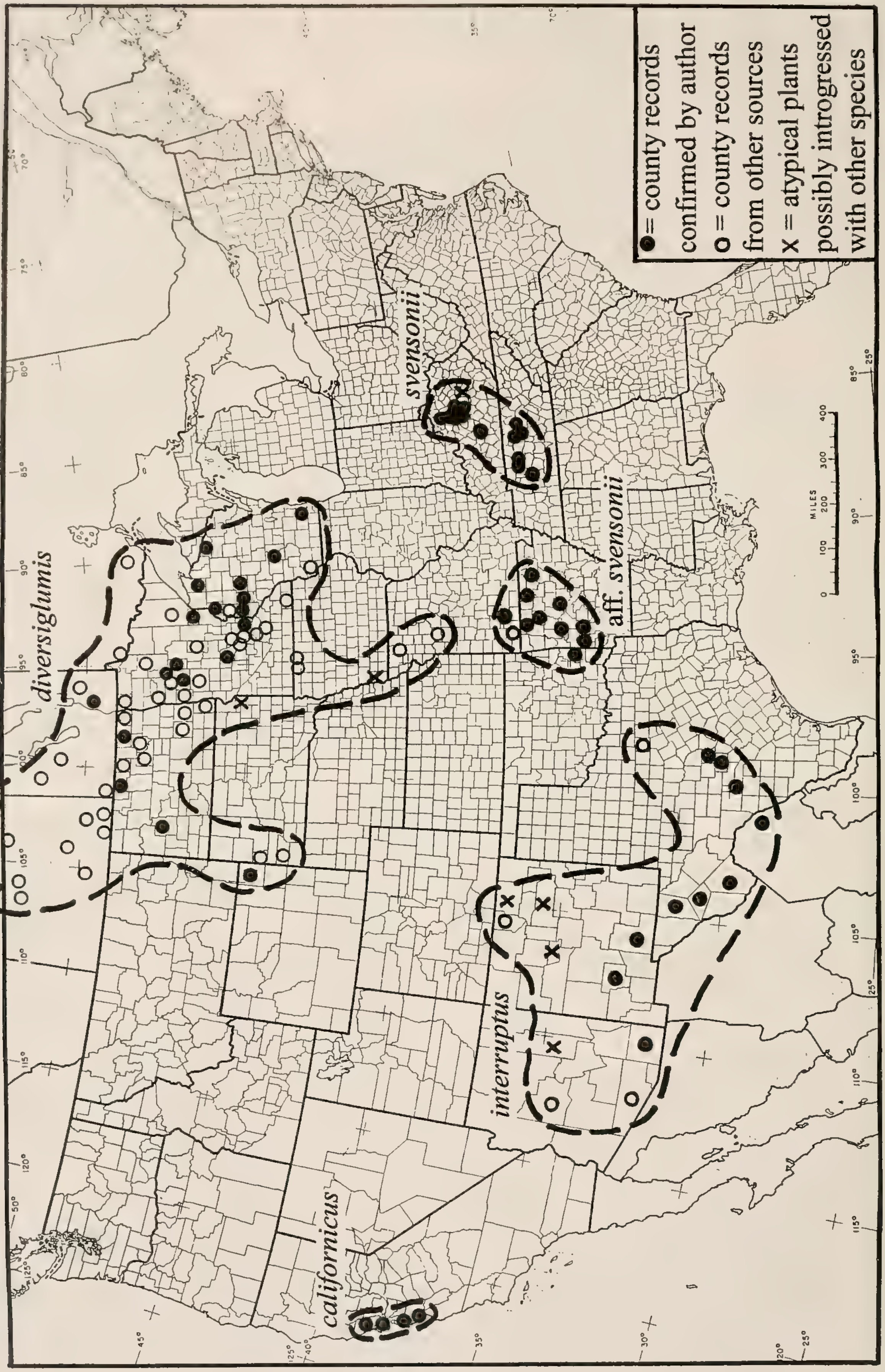


Figure 1. Map showing ranges of *Elymus interruptus*, *E. svensonii*, *E. diversiglumis*, and *E. californicus*. This is based on U.S.A county-records plus any collections known from Canada and Mexico. See text for collection details. The “atypical” plants are mapped only if no typical plants are known from the county.

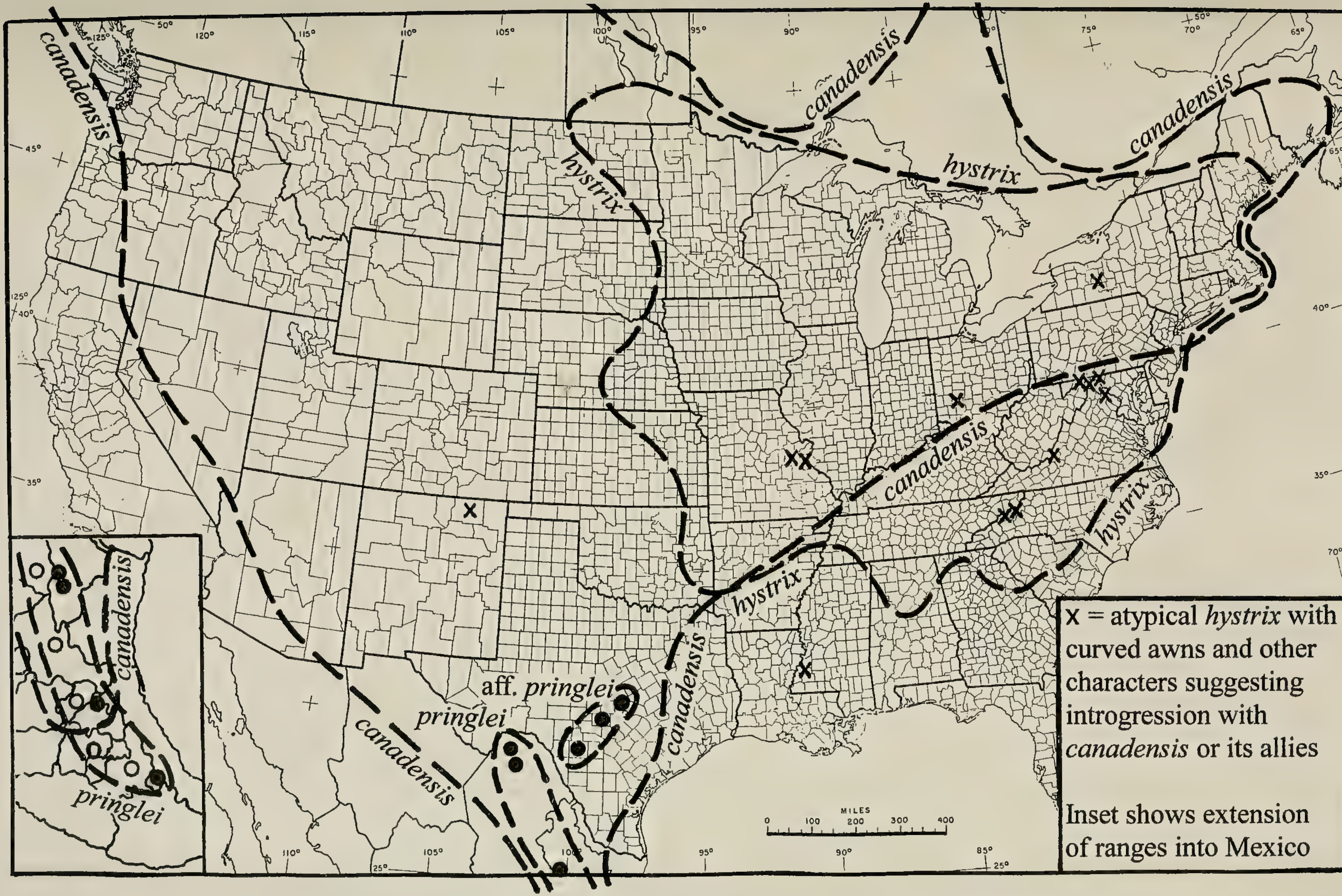


Figure 2. Map showing approximate ranges of *Elymus hystrix* and *E. canadensis* (dashed lines without dots), plus records *E. pringlei* and related plants (dashed lines enclosing dots as in Figure 1). Ranges of *hystrix* and *canadensis* are based on herbarium collections examined by this author and on other reliable sources (cited in this paper or reviewed by M.E. Barkworth, pers. comm.). These ranges may exclude a few outlying records that still need confirmation; the range of *canadensis* does exclude several misidentifications and dubious records in the southeastern U.S.A. The "atypical" *hystrix* records do not include the common introgressants with sympatric *diversiglumis* and *svensonii* (see Introduction). See text for collection details of *E. pringlei*.

was an eastward expansion of some Great Plains grasses into the Interior Low Plateaus during past xerothermic climatic eras, as indicated by such features as disjunct patches of *Bouteloua curtipendula* (Michx.) Torr. and *Muhlenbergia cuspidata* (Torr.) Rydb. on xeric limestone outcrops in central Kentucky (see also Delcourt et al. 1986; Yatskievych 1999).

(3) Within the range of *E. interruptus* sensu stricto (Figure 1), there may be some introgression with *E. canadensis* (see below), but this is not well documented. The closest known *E. hystrix* is 300–400 miles to the northeast in eastern Oklahoma (Figure 2), though there is an anomalous possible hybrid from Colfax Co., New Mexico: *Silveus 4928* (TEX).

Given Church's (1967) treatment of *Elymus diversiglumis,* this species is relatively well known and it is not treated further below. It is the most widespread species of the *interruptus* group, extending north onto much glaciated land and further south in scattered locations including the Black Hills of eastern Wyoming and western South Dakota as well as the Driftless Area of southern Wisconsin and Iowa. In contrast, the other taxa treated in this paper have much smaller or more fragmented ranges further south. Are they, then, remnants of one or more formerly widespread species isolated, perhaps, since the Tertiary era or did they originate from independent hybridizations, perhaps during the large regional shifts in vegetation during the Quaternary era?

Such questions will be difficult to address, even with intensive molecular research. The purpose of this paper is simply to provide updated morphological descriptions of these taxa, to map their distributions, and to develop the general hypothesis of independent origin for the several apparent entities in this group. These materials are somewhat provisional, but they do constitute a foundation for more detailed research. The third paper in this series will incorporate these taxa into a synoptic key for all North American *Elymus* species with paired spikelets.

ELYMUS INTERRUPTUS SENSU STRICTO

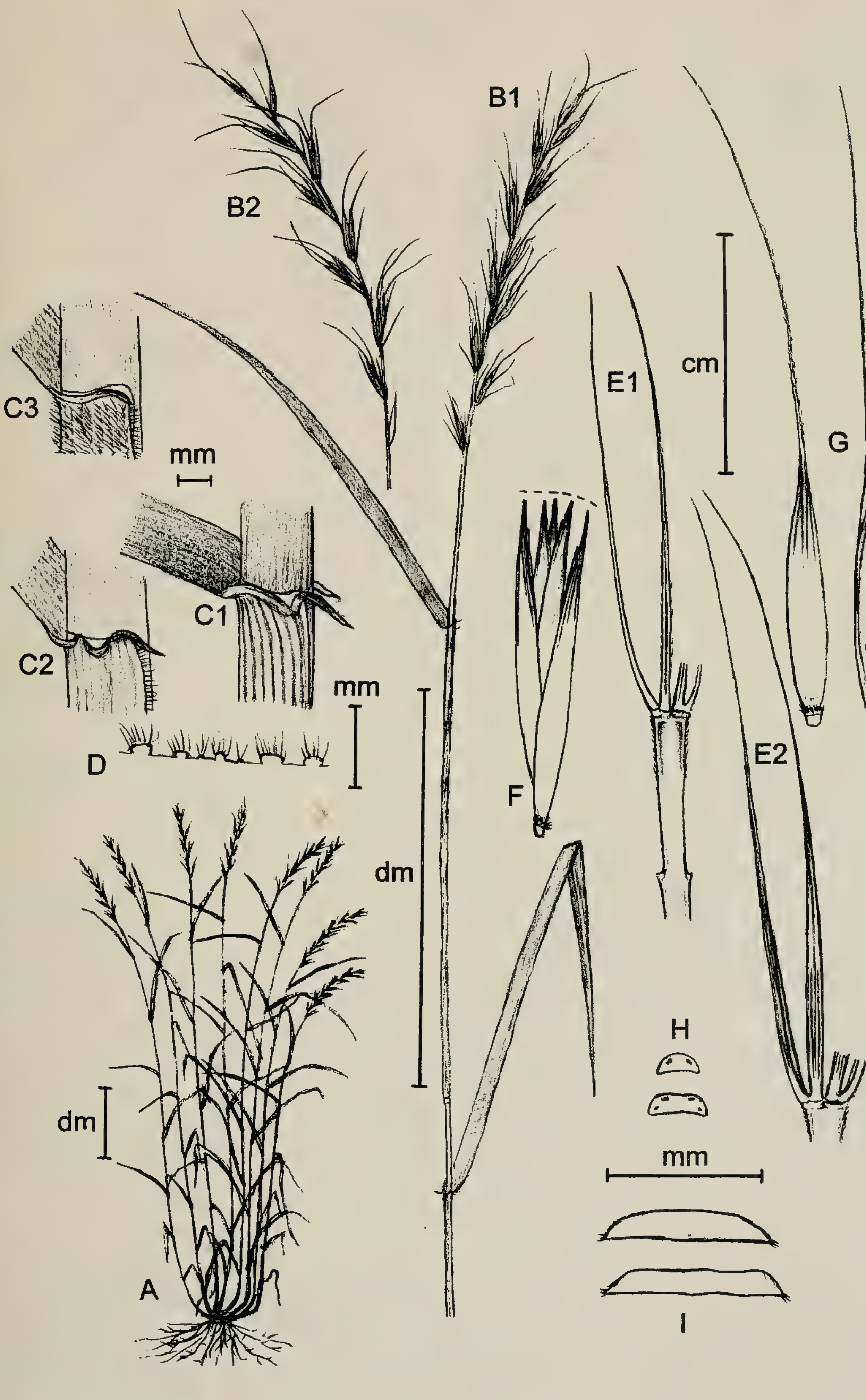
Although *Elymus interruptus* was first described in 1862, it remains poorly collected and there is an ongoing need to improve its description and to document its distribution. An amended description follows.

Elymus interruptus Buckley (Figure 3), Proc. Acad. Nat. Sci. Philadelphia [14]:99 (1862). *Elymus canadensis* var. *interruptus* (Buckley) G.L. Church, Rhodora 69:133 (1967).

Plants cespitose, usually glaucous (with pruinose bloom on several parts). Culms 50–100 cm, erect or the base somewhat decumbent; nodes mostly exposed. Sheaths glabrous or occasionally hirsute; ligules up to 1 mm long; auricles 0–2 mm, pale or reddish brown; blade 3–9 mm wide, lax, densely short-pilose, hispidulous or scabridulous above, especially on the veins, pale green (under any bloom). Spikes 5–20 cm long, 2–5 cm wide including awns, erect or slightly nodding, with 2 spikelets per node; internodes 5–14 mm, ca. 0.2–0.3 mm thick (at thinnest section), without pronounced dorsal angles. Spikelets 9–22 mm long (excluding awns), more or less spreading, with 2–5 florets (including terminal rudiment). Glumes 15–30 mm long including the weakly differentiated, straight or flexuous awn, 0.2–0.5(0.7) mm wide, linear-setiform to setaceous, glabrous to scabridulous, 1–3-veined; lemmas 7–10 mm, glabrous to scabridulous, or occasionally hirsutulous, especially near the margins, the awn 15–22 mm, straight to moderately outcurving; paleas 6–9 mm, obtuse or narrowly truncate, often emarginate; anthers

→

Figure 3. *Elymus interruptus* Buckley (drawn from *W.V. Brown* 3484 unless noted). A. Habit.; B. Upper portion of culm with mature spike, viewed on plane with alternating spread of spikelets (B2 from *J. Smith 692*); C. Sheath summit and blade base (C2 from *B.C Tharp 193*; C3 from *J. Smith 692*); D. Adaxial leaf surface, showing veins and hairs; E. Mature rachis internode and glumes, viewed in plane of spikelet spread (with abaxial view of central glume in spikelet and largely side view of lateral glume; E2 from *B.C Tharp 193*); F. Spikelet, with lateral view of florets; G. Mature floret in abaxial view (left) and adaxial view (right); H. Cross-sections of mature, indurate glume bases; I. Cross-sections of central rachis internodes.


B1
B2
C3
mm
C1
C2
mm
D
E1
cm
G
F
E2
dm
dm
A
H
mm
I

2–4.5 mm, usually evident from May to June. Chromosome number (2n) = 28.

Type. U.S.A., TEXAS: Llano Co., *S.B. Buckley s.n.* (PH, HOLOTYPE).

Other collections. All of the following have been examined by the author [with comments in squared brackets], except those in curved brackets { }, which have been cited by Church (1967) or M. Barkworth (Utah Stata University, pers. comm.). MEXICO. COAHUILA: Villa Acuna, Sierra del Carmen, Canyon de Sentenela on Hacienda Piedra Blanca, moist stream side, 6 Jul 1936, *F.L. Wynd & C.H. Mueller 529* (ARIZ, GH, WIS). U.S.A. ARIZONA: Cochise Co., Garden Canyon, Fort Huachuca Military Reserve, *Goodding 125–62* (ARIZ, NCU); {Pima Co., mapped by Barkworth; Yavapai Co., Oak Creek Canyon, *Deaver 2389* (ARIZ), cited by Church}. NEW MEXICO: Sierra Co., 10 Jul 1904, *Metcalfe 1100* (NMCR); {Taos Co., mapped by Barkworth}. TEXAS: Brewster Co., in creek bed of Oak Creek, 3 Jun 1937, *B.B. Warnock 20201* (US); Culbertson Co., Sierra Diablo Mts., right fork Little Victorio Canyon, very moist conditions, 15 Jun 1973, *S. Sikes & J. Smith 612* (TEX); Gillespie Co., Balanced Rock, Fredericksburg, 1/6 Jun 1930, *B.C. Tharp 193/s.n.* (MO, TEX) [glumes thicker than normal]; Gillespie Co., Enchanted Rock, near Fredericksburg, 1 Jun 1930, *B.C. Tharp & E. Whitehouse 7534* (TEX); Jeff Davis Co., along rocky banks of creek, Little Ajuga Canyon, Davis Mts., 12 Jun 1928, *E.J. Palmer 34544* (MO, GH) [spike mature but the base still sheathed]; [Jeff Davis Co.?], Fort Davis, rich open moist soil, 8 Jun 1940, W.A. Silveus 5875 (TEX); Llano Co., between Enchanted Rock and Sandy Creek, rich granitic soil in shade, 8 Jul 1948, *W.V. Brown 3484* (TEX); {also cited by Church from Llano Co., but not found at US, are *Wolf 3123* (US), *Smith* (US 1019698), *Reverchon* (US 64974), and *Church & Brown 1041* (BRU)}; Real Co., Lost Maples State Natural Area, confluence of Cam Creek and drainage 13, [with] *Verbesina virginica, Quercus texana, Juglans major,* 18 Jun 1975, *J. Smith 692* (TEX) [sheaths hirsute].

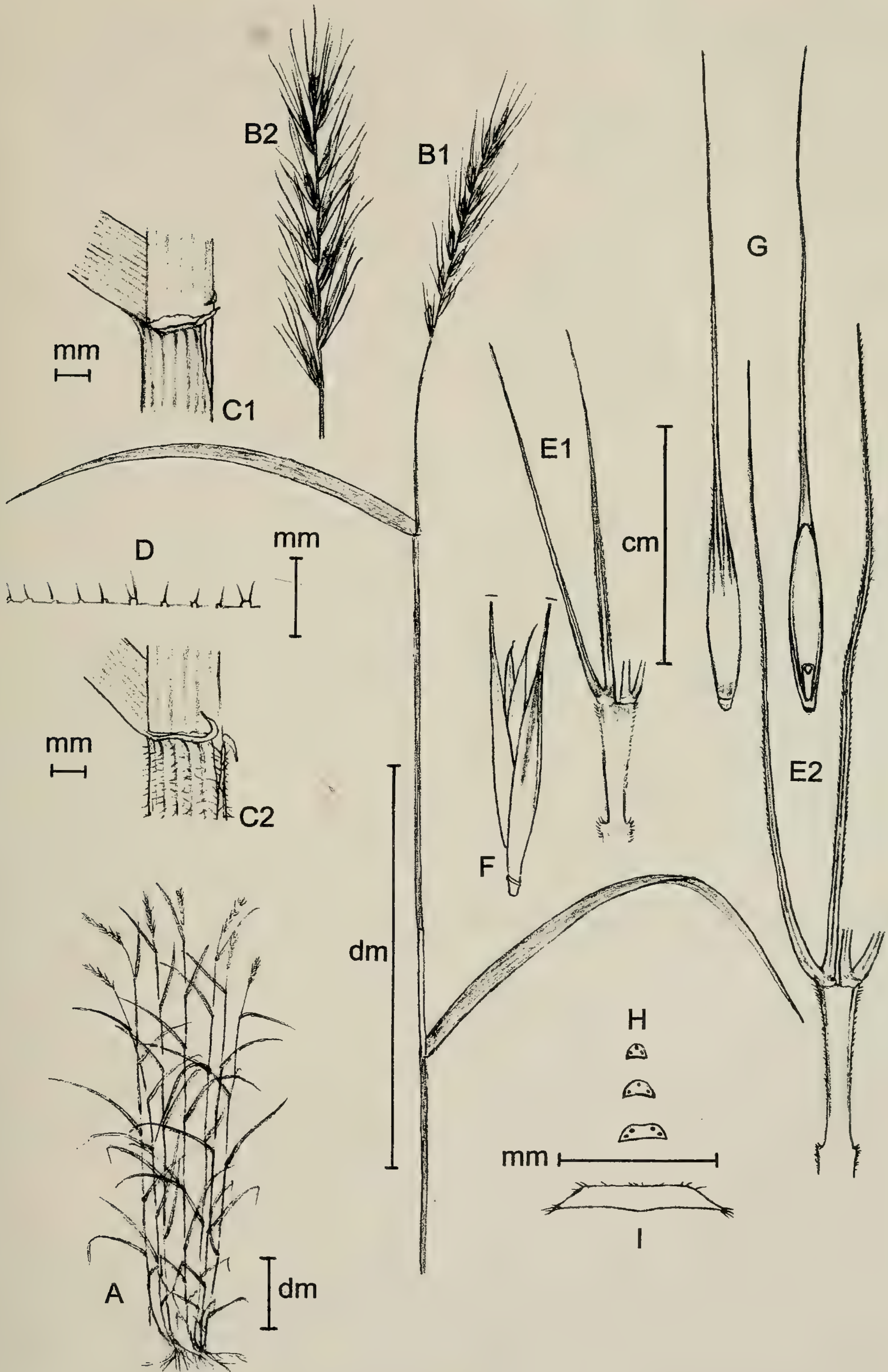
Elymus interruptus is known from western Texas, New Mexico, and Arizona in the U.S.A, and from Coahuila in northeastern Mexico. Its typical habitats are on relatively moist, rocky soil, often in canyons and along streambeds, with open woods and thickets.

This species appears closer to *E. canadensis* than to *E. hystrix,* whereas the more eastern *E. svensonii* and more northern *E. diversiglumis,* with more reduced glumes, appear closer to *E. hystrix.* The few collections that appear intermediate between *E. interruptus* and *E. canadensis* are excluded from the above list. However, it is notable that some of these are from well north of the documented range of typical *E. interruptus*—ARIZONA: Navajo Reservation, canyon floor, Jul 1916, *Anon. s.n.* (ARIZ, MO); IOWA, Mills Co. [data not available] (NCU); and NEW MEXICO, Bernalillo Co., Isleta Pueblo, irrigation ditch and Rio Grande River bottom, sandy loam, 21 Oct 1966, *J.R. Crutchfield 2393* (TEX); San Miguel Co., House Trap, head of Cuevas Canyon, 6200–6300 ft, 5 miles S of Rte 104, 16 Aug 1982, *S.R. Hill & P.A. Levandoski 11914* (OKL). Much more field work is needed to examine this possible introgression.

An anomalous collection that may have similarities to both *Elymus hystrix* and *E. interruptus* is of interest here, from NEW MEXICO: [Colfax Co.], wooded bank, Cimarron, 6 Jul 1939, *Silveus* 4928 (TEX). This specimen was listed by Church (1967) under his "atypical" *E. hystrix* group with filiform glumes. Unfortunately all the florets are lost, but the glumes are more widely spreading than typical *E. interruptus,* and rachis internodes are only ca. 5 mm long. This specimen suggests that

→

Figure 4. *Elymus pringlei* Scribn. & Merr. (drawn from *Johnston et al. 118123* unless noted). A. Habit; B. Upper portion of culm with mature spike, viewed on plane with alternating spread of spikelets (B2 from *Henrickson 15045*); C. Sheath summits and blade base (C2 from *Gould & Ortega 6352*); D. Adaxial leaf surface, showing veins and hairs; E. Mature rachis internodes and glumes, viewed in plane of spikelet spread (with abaxial view of central glume in spikelet and largely side view of lateral glume; E2 from *Henrickson 15045*); F. Spikelet, with lateral view of florets; G. Mature floret in abaxial view (left) and adaxial view (right); H. Cross-sections of mature, indurate glume bases; I. Cross-section of central rachis internodes.


B2
B1
G
mm
C1
E1
cm
D
mm
mm
C2
E2
F
dm
H
mm
I
A
dm

plants closely related to *E. interruptus* or *E. hystrix* may still be found in northern New Mexico or nearby. The closest documented *E. hystrix* is in eastern Oklahoma. Does this New Mexico plant have a distinct origin, perhaps from some isolated introgressed population?

Key questions for future research on *Elymus interruptus* are as follows.

(1) Did this species originate by simple divergence from *E. canadensis* or did it result from hybridization between *E. canadensis* and *E. hystrix* or an ally?

(2) In the latter case, did *E. hystrix*, as one of the parental species, once extend further west or did a distinct species within this region, perhaps now extinct, act as the parent instead?

ELYMUS PRINGLEI

Elymus pringlei Scribn. & Merr. is a Mexican species, as treated by Beetle (1991), which has not yet been compared thoroughly with other *Elymus* species from the U.S. and Canada. However, Scribner and Merrill (1901) did initially compare this species with *E. interruptus*, and Church (1954, p. 192) noted that "all of these southern taxa [*E. pringlei*, *E. interruptus* and *E. canadensis* var. *brachystachys* (Scribn. & C.R. Ball) Farw.] appear to belong to a single species complex."

Based on collections at GH and TEX, an amended description of *E. pringlei* is as follows.

Elymus pringlei Scribn. & Merr. (Figure 4), USDA Div. Agrostol. Bull. 24:30 (1901).

Plants cespitose, usually somewhat glaucous (with pruinose bloom in several parts). Culms 50–110 cm, erect or somewhat geniculate at base; nodes mostly exposed. Sheaths glabrous or occasionally pilose (somewhat retrorsely); ligules ca. 1 mm long, erose; auricles ca. 1 mm, pale or brownish; blades 3–12 mm wide, lax, thinly scabridulous or hispidulous to pilose on veins above, glaucous-pruinose above. Spikes 4–12 cm long, 2–3 cm wide including awns, erect or slightly nodding at culm summit, the base sometimes sheathed, with 2 spikelets per node; internodes 3–6 mm, tapering greatly in width (ca. 50%) from apex to base, ca. 0.2 mm thick (at thinnest section), with two hispid dorsal angles. Spikelets 18–25 mm long excluding awns, appressed, with 3–5(6) florets (including terminal rudiment). Glumes 12–22 mm long including the undifferentiated straight awn, 0.2–0.3(0.6) mm wide, subulate to setaceous, glabrous, 0–1-veined (plus thickened margins that may contain vascular bundles); lemmas 8–10 mm, usually scabrous-hispid to thinly strigose-pubescent, at least distally, the awn 8–22 mm, straight or flexuous; paleas ca. 7–8 mm, obtuse or acute, often emarginate; anthers 2.5–4 mm, evident (probably) in May to June. Chromosome number unknown.

Type. MEXICO, HIDALGO: wet soil, valley near Tula, 2200 m, 8 Jun 1897, *C.G. Pringle 6637* (US 316873, HOLOTYPE).

Other collections examined. MEXICO, COAHUILA: Sierra Jardin, Canyon Hundido on N side of Pico de Centinela, *Quercus, Pinus, Acer, Tilia,* etc., 1500–2250 m, 27 Jun 1973, *M.C. Johnston et al. 11812B* (TEX); south end of Sierra Maderas del Carmen, Canyon de la Fronteriza, ryolite area, [with] *Quercus gravesii, Acer, Fraxinus velutina, Vitis, Juglans, Diospyros,* etc., 6 Aug 1976, *J. Henrickson 15045* (TEX) [atypical, see below]. NUEVO LEÓN: Sierra Madre Mts., Monterey, 4/6 Aug 1933, *C.H. & M.T. Mueller 429* (GH, TEX); Sierra Madre Oriental, ascent of Mesa de la Camisa about 15 miles southwest of Galeana, co-subdominant over large areas of the [lower?–illeg.] pine-oak wood, 22 Jul 1934, *C.H. & M.T. Mueller 1169* (GH); Galeana, by spring-fed pool in gulch, 5400 ft, 31 Jul 1939, *V.H. Chase 7699* (GH) [leaves broader than others]; Chipinque, pine woodland, 1 Jul 1947, *F.A. Barkley et al. 7148* (TEX); Sierra Anahuac, Chinpinque, 1800 m, 14 Jun 1952, *F.W. Gould & J. Ortega 6352* (TEX). HIDALGO: wet soil, valley near Tula, 2200 m, 24 Oct 1896, *C.G. Pringle 7165* (US); wet soil, Dublan, 6800 ft, 19 Sep 1902, *C.G. Pringle 11222* (GH). VERACRUZ: region d'Orizaba, 1865–66, *M. Bourgeau 167* (GH, P); Orizaba, [1860s?], *Botteri 704* (GH).

Elymus pringlei is known only from the Sierra Madre Oriental of northeastern Mexico. In addition to the Mexican states listed above, Beetle (1991) mapped the species from San Luis Potosí, Querétaro, Mexico City, and Puebla. It occurs at 1500–2250 m above sea level, on moist slopes and in canyons, with woods of pines and deciduous trees.

Elymus pringlei has glumes generally inter-

mediate in development between allies of *E. hystrix* and more typical *Elymus* species with paired spikelets. As in *E. diversiglumis* and *E. svensonii,* the glumes are subulate to setaceous, tapering from the base and with little superficial evidence of veins. However, unlike the unequal or vestigial glumes of those three species, the glumes of *E. pringlei* are consistently well developed in length at all nodes of the spike and those of each pair are more or less equal.

It is conceivable that *Elymus pringlei* originated from hybridization between a species like *E. hystrix* and a species like *E. canadensis.* However, *E. pringlei* lacks the awn curvature typical of *E. canadensis.* The only *Elymus* taxa with paired spikelets that have known ranges overlapping with *E. pringlei* are *E. interruptus* and *E. canadensis* var. *brachystachys.* Even though both these taxa have more developed glumes than *E. pringlei*—the glumes being broadest above the base and with distinct veins—the general similarity of these two taxa to *E. pringlei,* with occasional intermediate collections, suggests that there might have been some introgression. Whether there was in the past, or perhaps still is in some unexplored canyon, a close ancestral link with *E. hystrix* as well, remains a matter for further speculation.

Elymus pringlei is to be expected in southwestern Texas and further field work should examine whether intermediates exist between this species and related taxa in Texas. It is notable that the northernmost collection listed above under *E. pringlei* appears somewhat atypical and may be transitional to *E. interruptus* or related plants in Texas: *Henrickson 15045,* from Coahuila, "54 miles SE of Big Bend National Park." This collection has relatively robust glumes, long rachis internodes, spikelets with up to 6 florets (including the terminal rudiment), and lemmas that are virtually glabrous (Figure 4). Moreover, three anomalous collections from the Edwards Plateau in Texas appear closely related, as presented below.

PLANTS SIMILAR TO *ELYMUS PRINGLEI* IN TEXAS

Three collections from the Edwards Plateau of Texas, previously identified as *Elymus interruptus* or *E. canadensis,* appear anomalous and may represent an undescribed taxon in this group. However, because so little material is available at present, and there are strong similarities with *E. pringlei* and *E. interruptus,* it would be imprudent to publish a new name here. The following provisional description can be used to guide future work.

Elymus sp., aff. ***pringlei*** Scribn. & Merr. (Figures 5.1 and 5.2).

Plants cespitose, glaucous (with pruinose bloom in several parts). Culms 70–110 cm, erect; nodes mostly exposed. Sheaths glabrous; ligules ca. 1 mm long, erose; auricle up to ca. 1 mm (or sometimes adherent to sheath summit), pale to purplish brown; blades 2–9 mm wide, lax (?), thinly scabrous-hirsute or densely short-pilose above, pale green (under the glaucous-pruinose bloom). Spikes 9–20 cm long, 2–2.5 cm wide including awns, straight to slightly nodding, with 2 spikelets per node; internodes (5)7–15(22) mm, with green bands down the concave sides, ca. 0.1–0.3 mm thick (at thinnest section), with slight dorsal angles, glabrous (except ciliolate margins). Spikelets 25–40 mm long excluding awns, appressed, with 5–8 florets (including the terminal rudiment). Glumes 14–24 mm long including the undifferentiated awn, 0.1–0.3 mm wide, setaceous, glabrous, 0–1-veined (excluding thickened margins); lemmas 8–12 mm, glabrous, the awn 8–25 mm, straight, flexuous or slightly curving; paleas 7–11 mm, obtuse or narrowly truncate to emarginate; anthers 4.5–6 mm, evident in May. Chromosome number unknown.

→

Figure 5. Texan plants similar to *Elymus pringlei* (5.1 drawn from *E.S. Nixon 531*; 5.2 from *V.L. Cory 29073*). A. Habit; B. Upper portion of culm with mature spike, viewed on plane with alternating spread of spikelets; C. Sheath summit and blade base; D. Adaxial leaf surface, showing veins and hairs; E. Mature rachis internode and glumes, viewed in plane of spikelet spread (with abaxial view of central glume in spikelet and largely side view of lateral glume); F. Spikelet, with lateral view of florets; G. Mature floret in abaxial view (left) and adaxial view (right); H. Cross-sections of mature, indurate glume base(s); I. Cross-section of central rachis internode.

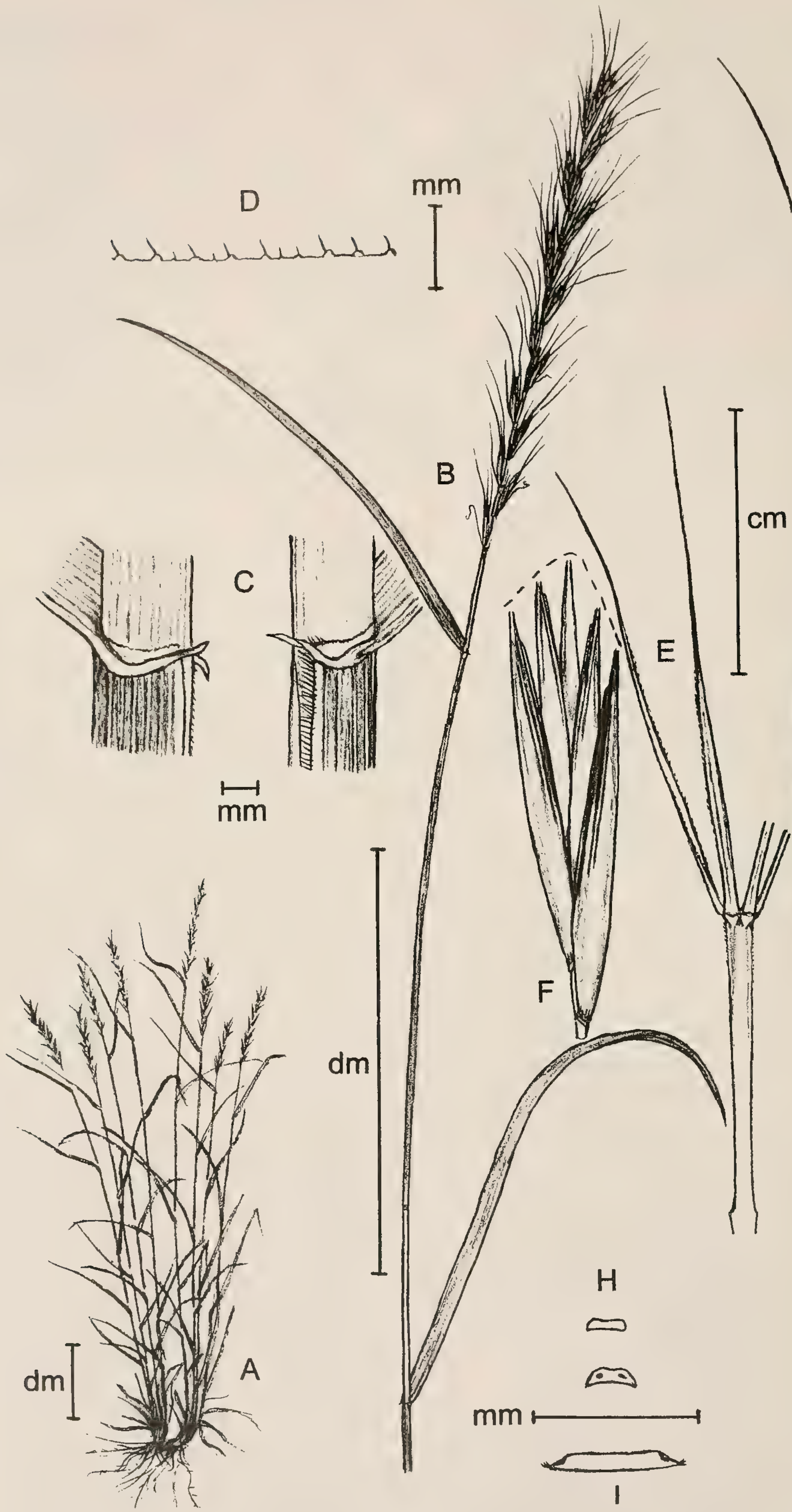


Figure 5.1.

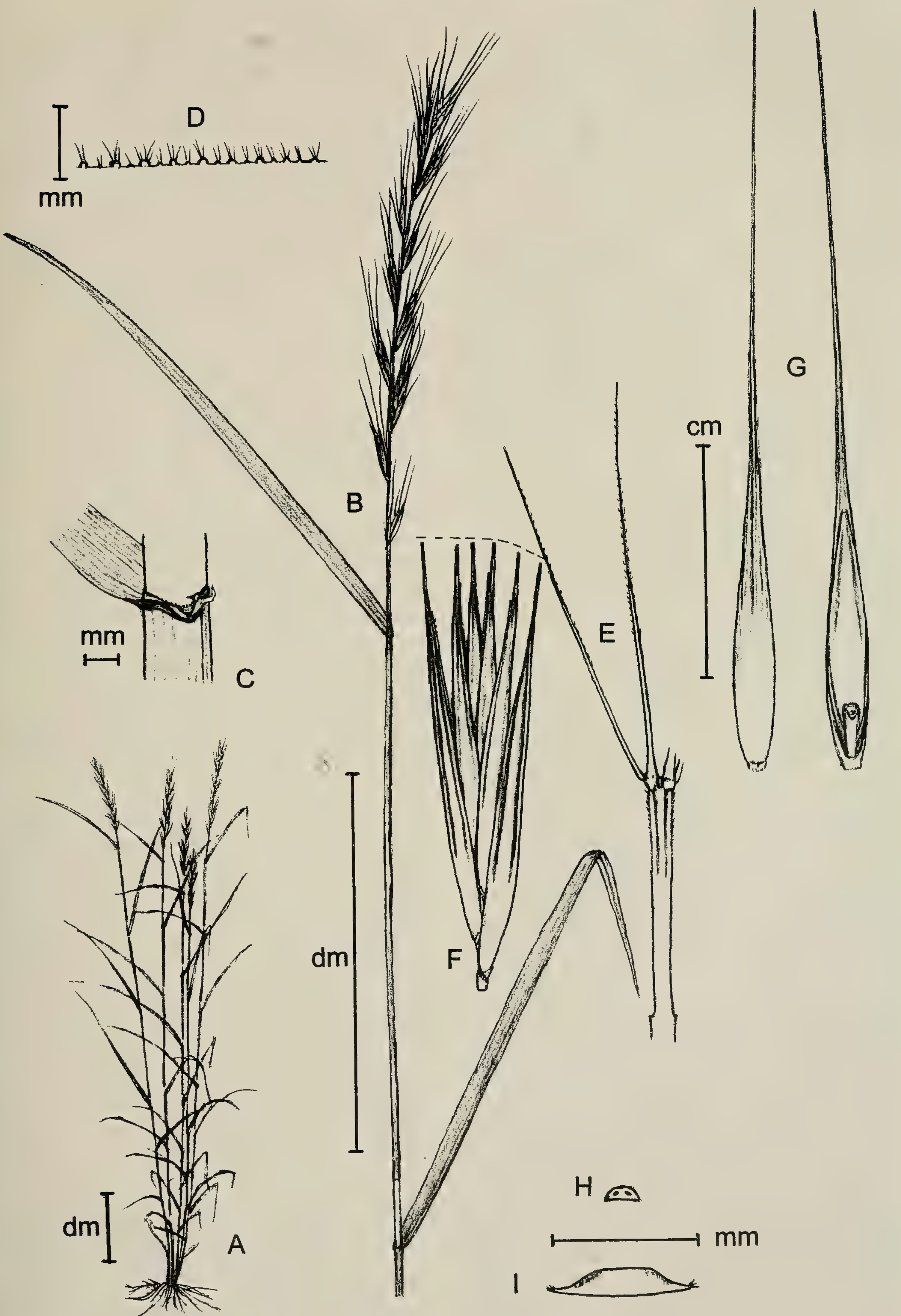


Figure 5.2.

Collections examined. U.S.A., TEXAS: Burnet Co., Inks Lake State Park, limestone bluffs, juniper woods along creek just east of HQ, 19 May 1983, *R. & G. Kral 70066* (VDB/SMU) [similar to *Nixon 531* but culms only 70–80 cm, blades 2–5 mm wide, spike ca. 10 cm long, with internodes 5–8 mm]; Gillespie Co., Serpentine Mounds about 9 miles north of Willow City, hilly area vegetated mainly with grasses, 18 May 1966, *E.S. Nixon 531* (TEX) [5–6 florets per spikelet, glumes up to 0.3 mm wide, with two veins, lemma awns slightly curving, anthers ca. 4.5–5 mm]; Uvalde Co., chalk bluff on Nueces River, 12 May 1938, *V.L. Cory 29073* (US 3039432) [5–8 florets per spikelet, glumes ca. 0.2 mm wide, without a distinct vein, lemma awns straight, anthers ca. 5–6 mm].

These plants do not exactly match any known taxon in current treatments, but they appear to have a close affinity with *Elymus pringlei* and *E. interruptus*. The large number of florets per spikelet (5–8) and the long anthers (4.5–6 mm) are unlike any known species of *Elymus* with paired spikelets in North America, although the anomalous, geographically isolated, octoploid (2n = 56) *E. californicus* (Bol. ex Thurb.) Gould [syn. *Hystrix californica* (Bol. ex Thurb.) Kuntze] has even longer anthers (6–8 mm). The plants described above are similar to the Mexican *E. pringlei* but differ in their more numerous florets, longer anthers, larger spikes with longer internodes, and details of pubescence. They are also similar to the sympatric *E. interruptus* and might provisionally be treated as a variant of that species. Alternatively, it is possible that these plants deserve new species status. Until there are more collections and *E. interruptus* itself is better understood, it seems best to reserve judgment.

These plants differ from typical *E. interruptus* in their larger spikelets (with 5–8 versus 2–5 florets), longer anthers (4.5–6 mm versus 2–3.5 mm), often longer rachis internodes (8–22 versus 5–14), typically narrower glumes (0.1–0.3 mm versus 0.2–0.5 mm), and slightly longer lemmas (8–12 mm versus 7–10 mm) with generally less curving awns. It seems unlikely that these plants are of recent hybrid origin from sympatric *E. interruptus* and another parent species in this region of Texas, because the differences from *E. interruptus* do not suggest a transition to *E. canadensis* or any other known species in North America. Apart from *E. interruptus* and the closely related *E. canadensis* var. *brachystachys*, no other *Elymus* taxa with paired spikelets are known in this region of southern Texas.

Also deserving consideration is the possible affinity of these Texan plants, like some species previously placed in *Hystrix* Moench (Barkworth 2000), to the genus *Leymus* Hochst. *Leymus* has a genome that is distinct from *Elymus* and generally differs in having rather long anthers (3–9 mm), short lemma awns (0–7 mm), setaceous to linear-lanceolate glumes (with 1–3 veins), strongly ribbed leaf blades, and long rhizomes. Also, *Leymus* generally occurs in relatively arid climatic zones or on xeric sites in humid zones. The plants described above do have relatively long anthers and setaceous glumes. However, their long lemma awns are unlike any known *Leymus* species. Their leaves do not appear strongly ribbed and rhizomes are not apparent. Interestingly, the octoploid *Elymus californicus* (syn. *Hystrix c.*) has been shown to have some genomic affinity with *Leymus* (Jensen and Wang 1997), but it also differs in its long lemma awns (16–33 mm) and weakly ribbed leaf blades. Moreover, its highly reduced glumes and mesic forest habitat would be anomalous for *Leymus*.

One might speculate that, like the mysterious *Elymus californicus*, these Texan plants are relics from a more mesic climatic era when *Elymus* species with reduced or vestigial glumes extended across western North America. Possibly their extinct ancestors, or close relatives, hybridized with *E. canadensis* to produce *E. interruptus*, just as *E. hystrix* appears to have hybridized with *E. canadensis* to produce *E. svensonii* and *E. diversiglumis* further north and east.

ELYMUS SVENSONII IN TENNESSEE AND KENTUCKY

Elymus svensonii was described from Tennessee over 30 years ago (Church 1967). This species was not recognized in Kentucky until the 1980s (Medley 1993), despite an early collection by C.W. Short in the 1830s (without locality, at KY). It is still not covered in recent floras of the region (e.g., Cronquist 1991).

Based on a much wider range of material than was available to Church, an amended description is provided here.

Elymus svensonii G.L. Church (Figure 6), Rhodora 69:134 (1967).

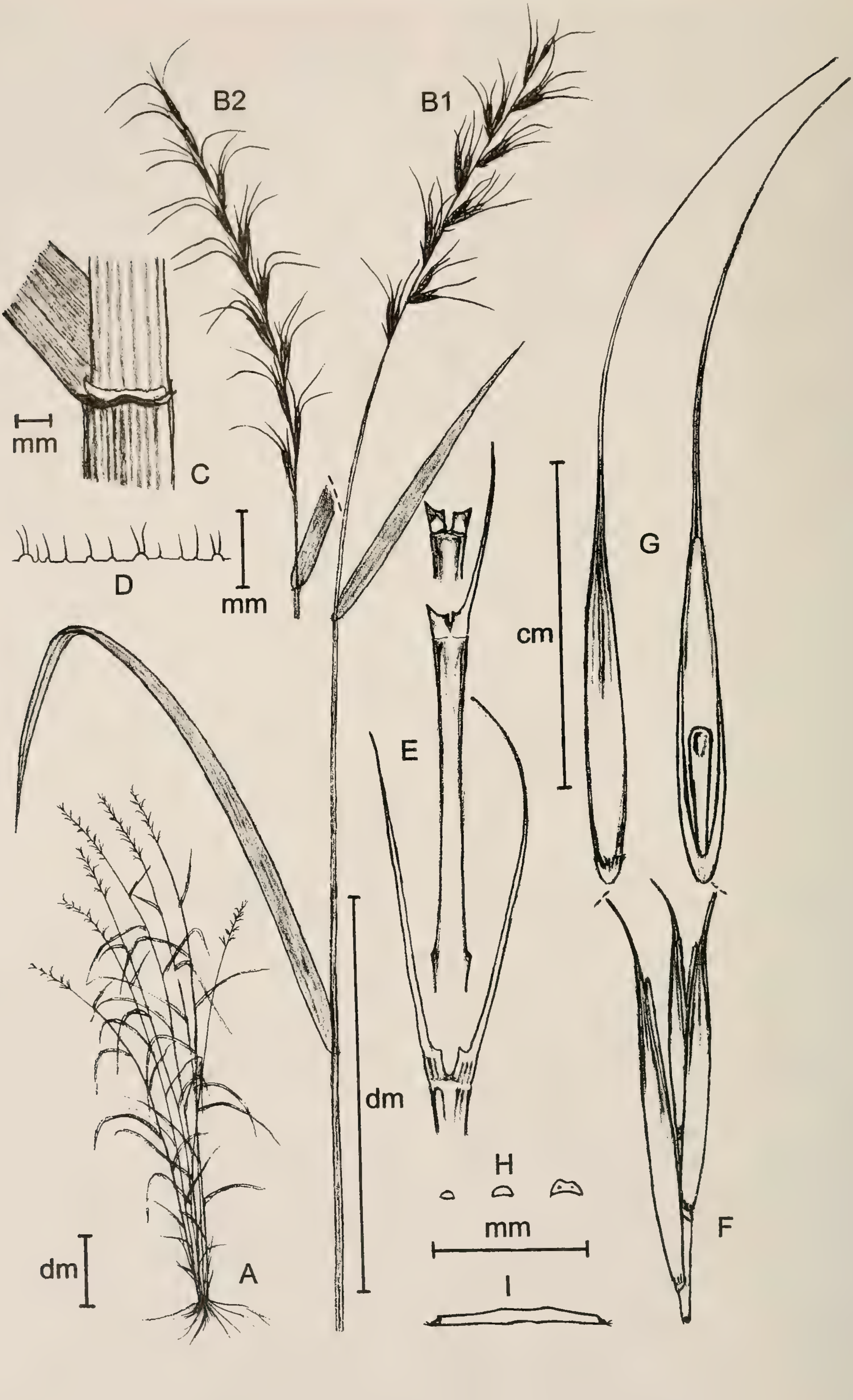
Plants cespitose, strongly glaucous (with pruinose bloom). Culms 50–110 cm, erect; nodes mostly exposed, often reddish brown. Sheaths glabrous or villous to hirsute, often somewhat purplish; ligules up to 1 mm long, often reddish brown; auricles (0)1–2 mm, purplish or reddish brown; blade 4–8(10) mm wide, lax, usually villous above. Spikes 10–16 cm long, 3–5 cm wide (including awns), nodding, with 2 spikelets per node; internodes (4)6–10(12) mm, thin, flexuous. Spikelets 10–15 mm excluding glumes, usually appressed, with 3–5 florets (including rudiment). Glumes sometimes virtually absent from the upper spikelets or throughout, often unequal, (0)1–15(18) mm long including the undifferentiated awn, 0.1–0.3 mm wide, subulate to setaceous, glabrous, 0–1-veined; lemmas 8–10 mm, usually glabrous (occasionally hispidulous on veins near apex), the awn (8)10–20(25) mm, moderately to strongly outcurving; paleas 7–9 mm, obtuse or truncate, occasionally emarginate; anthers 3–5 mm, usually evident from mid-June to early July. Chromosome number unknown.

Type. U.S.A., TENNESSEE: Davidson Co., steep limestone bluffs on the Cumberland Rv. just N of Donelson, *Church 2527* (BRU, HOLOTYPE; GH, US 2489482, ISOTYPES).

Other collections examined. Only one noted per county in KY. U.S.A., KENTUCKY: Adair Co., near Buffalo Bluff above Green River (lat 37.14.24, long 85.15.28), shrubby forest on south face with gravelly siltstone-limestone soil, 28 Sep 2000, *M. Hines & A. Covert s.n.* (KY); Anderson Co., near Lover's Leap, 3 Aug 1995, *R. Mears s.n.* (KY) [probably introgressed with *E. hystrix*]; Fayette Co., 1000–2000 ft north of Valley View Ferry, 17 Aug 1995, *R. Mears s.n.* (KY); Franklin Co., Hwy 421 bluff on Kentucky Rv., 21 Jun 1987, *M. Medley 16807* (KY); Garrard Co., Dix Rv., crest of narrow ridge on Duggins Farm, 7 Jul 1987, *J. Campbell s.n.* (KY); Jessamine Co., upper slopes along Kentucky River upstream of US 68, 10 Aug 1995, *J. Campbell s.n.* (KY); Mercer Co., narrow ridge at mouth of Shaker Cr. (WKY); Owen Co., near Cedar Creek S of Monterey, 8 Sep 1995, *D. White s.n.* (KY); Woodford Co., dry Kentucky Rv. slopes near Buck Run, 10 Aug 1995, *M. Hines s.n.* (KY). TENNESSEE: Cheatham Co. [data not available] (VDB/SMU); Davidson Co., *H.K. Svenson 9452* (BKL, JEPS, U.S.—PARATYPE) [not found at MO but reported by Church (1967)]; Davidson Co., Donelson community near Nashville, Todd's Knob, limestone bluff at mouth of Stones River, 21 Aug 1980, *P. Somers et al.* (VDB); same locality, 21 Sep 1994, *A. Shea 94–002* (VDB); De Kalb Co., Caney Fk. bluff along Hwy 141 below Center Hill Dam, 1 Aug 1987, *M. Medley 17690* (KY); Hickman Co., rocky bluff of Piney River, at river mile 0.5, 17 Aug 1999, *C. Nordman s.n.* (TENN); Putnam Co., calcareous bluffs above Caney Fork River, by I-40 at Buffalo Valley, 6 Jul 1973, *R. Kral 50529* (VDB); same locality, 5 Jun 1975, *R. Kral 55946* (VDB); Putnam Co., Caney Fork, 1 Aug 1987, *M. Medley 17693* (KY); Putnam Co., dolomite ledges amongst juniper, by I-40 crossing of Caney Fork River, east side, frequent, 22 Jun 1994, *R. Kral 83571* (VDB); same locality, 6 Jun 1991, *M. Pyne 91–038* (VDB); Smith Co., limestone bluffs of Caney Creek by I-40 ca. 1 mile west of county line, 12 Jun 1987, *R. Kral 74032* (VDB).

Elymus svensonii is known mostly from dry, rocky soils in open forest on Ordovician limestone bluffs along the Cumberland River and its Caney Fork in the Central Basin of Tennessee, and along the Kentucky River and tributary ravines in the Inner Bluegrass region of Kentucky. In addition, C. Nordman (Tennessee Heritage Program, pers. comm.) has recently discovered this species along calcareous Silurian bluffs of the Piney River (a tributary of Duck River) in Hickman Co., Tennessee, transitional to the western Mississippian Plateaus (or "Highland Rim"). Also, M. Hines (Kentucky State Nature Preserves Commission) has discovered it in Adair Co., Kentucky, on bluffs of the Green River in the northern Mississippian Plateaus. Further west, some plants from the Ouachita and Ozark mountains are similar to typical *E. svensonii*, but these are treated separately below.

Not listed above are the many apparent introgressants with *Elymus hystrix* that have


B2
B1
C
mm
D
mm
G
cm
E
dm
H
mm
F
I
dm
A

been found within the range of *E. svensonii.* An early example in Tennessee is from Davidson Co., Nashville, 1885, *Gattinger* (US 1021372). More notable, however, are records of apparent introgressants from just outside the range of typical plants, including the following in Kentucky: Harrison Co., west of railroad & S Fk. Licking Rv. 1/4 mile south of Old Lair Road bridge, 31 Aug 1995, G. Libby & R. Mears 1204 (EKY); and a sight record from Henry Co. by M.E. Medley (University of Louisville, pers. comm.). There is also an anomalous collection from Appalachian foothills in Kentucky: Estill Co., Zion Mt., north of Red Lick Cr. on narrow ridge, 8 Apr 1990 [overwintered], *J. Campbell s.n.* (KY). This collection resembles *E. svensonii,* except that its rachis internodes are only 2–4 mm long. Possibly, it is derived from a plant like *E. svensonii* but hybridized with *E. virginicus.* The limestone cliffs in that region of Estill Co. have other disjunct populations of western xerophytes, including *Bouteloua curtipendula* (Michx.) Torr., *Muhlenbergia cuspidata* (Torr.) Rydb., and *Symphoricarpos albus* (L.) S.F. Blake.

Elymus svensonii, like *E. diversiglumis* further north (Church 1967), may be derived from hybrids between *E. hystrix* and *E. canadensis,* although the latter currently has its eastern limit 50–100 miles west of *E. svensonii* (Figure 2). Populations with relatively short or vestigial glumes appear largely introgressed with *E. hystrix* and are frequent within the range of typical *E. svensonii. Elymus svensonii* also hybridizes naturally with *E. virginicus* and probably other species (collections at KY). Artificial crosses with *E. interruptus* have been successful, but those with *E. diversiglumis* have not (Church 1967).

OUACHITA AND OZARK PLANTS SIMILAR TO *ELYMUS SVENSONII*

On some of the high ranges of the central Ouachitas and in the western Ozarks, there is another group of plants with reduced glumes and curving awns. These have been treated as *Elymus interruptus* by several authors (e.g., Smith 1991; Steyermark 1963), or just filed in herbaria as atypical forms of *E. hystrix.* However, these plants appear most similar to *E. svensonii.* A provisional description is as follows.

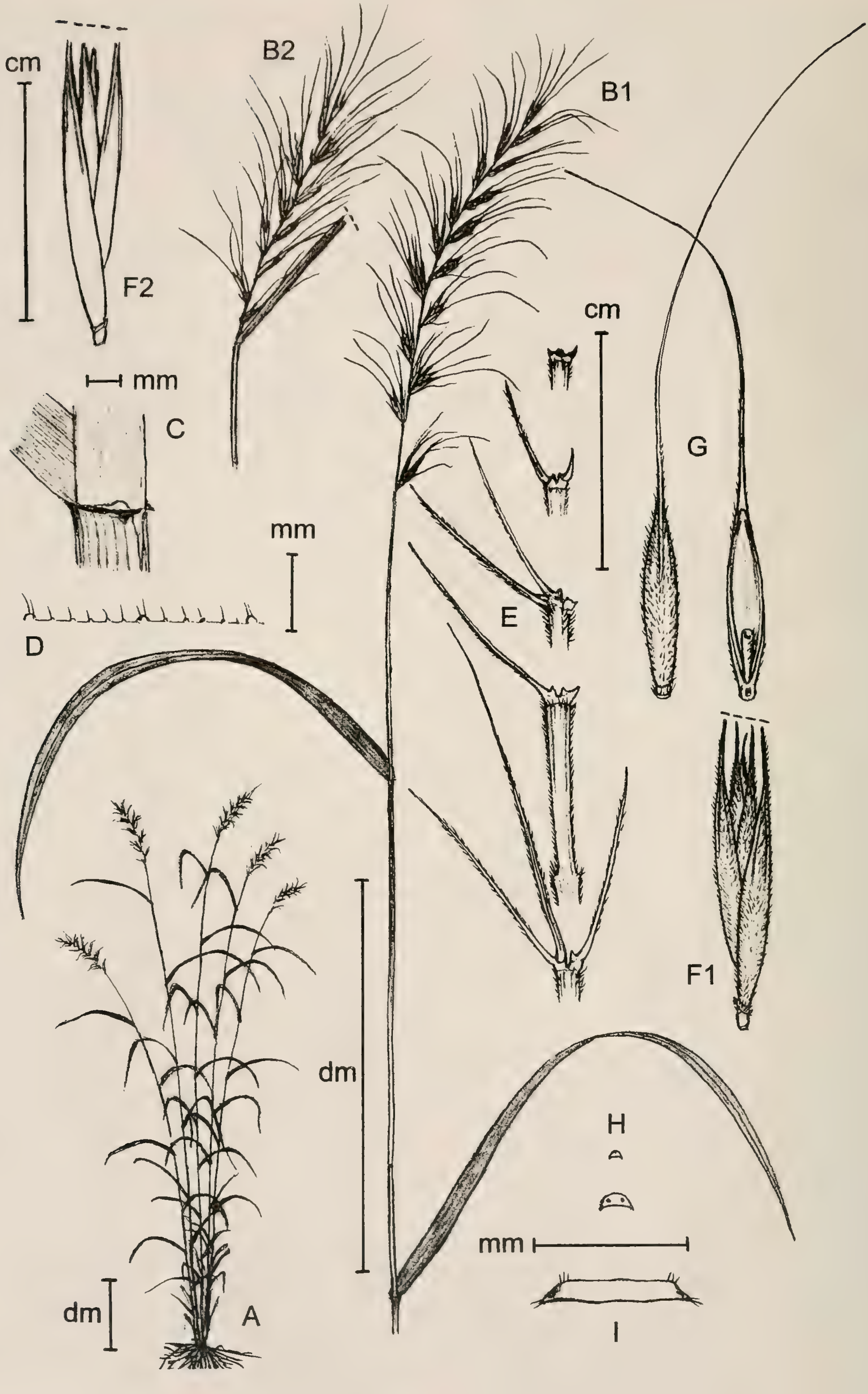
Elymus sp., aff ***svensonii*** G.L. Church (Figure 7).

Plants cespitose, often somewhat (but not strongly?) glaucous. Culms 50–120 cm, erect; nodes exposed or covered, often reddish brown or blackish. Sheaths generally glabrous, or with the summit sometimes pubescent; ligules up to 1 mm long, often reddish brown; auricles 1–2 mm, often reddish brown or blackish; blades 3–11 mm wide, lax, glabrous or short pilose above. Spikes 10–18 cm long, 3–5 cm wide, slightly nodding, with 2 spikelets per node; internodes (5)7–13(18) mm, flexuous, with green bands down the sides, ca. 0.2 mm thick (at thinnest section), with two hispid dorsal angles. Spikelets 10–15 mm long excluding awns, usually appressed, with 3–5 florets. Glumes vestigial, or restricted to lower nodes, or throughout, often unequal, 0–15(20) mm long (including the undifferentiated awn), 0.1–0.3 mm wide, subulate to setaceous, glabrous, 0–1-veined; lemmas 8–10 mm, pubescent or occasionally glabrous, the awn (10)20–30(35) mm, slightly to strongly outcurving; paleas 7–9 mm, obtuse to truncate or emarginate; anthers ca. 2.5–3 mm, evident in June. Chromosome number unknown.

Collections examined. U.S.A., ARKANSAS: Baxter Co., rocky shaded bluff, White Rv., P.O. Lakeview, Bull Shoals Dam Reservoir, 600 ft., 1 Jul 1950, *D. Demaree 29337* (OKL, TEX) [up to 5 florets, lemmas pubescent]; Carroll Co. [data not available] (NCU); Conway Co., Petit Jean State Park, rocky

←

Figure 6. *Elymus svensonii* G.L. Church (drawn from *Medley 16807* unless noted). A. Habit; B. Upper portion of culm with mature spike, viewed on plane with alternating spread of spikelets (B2 from and *T. Bloom s.n., 18 Jul 1990*); Cfj. Sheath summit and blade base; D. Adaxial leaf surface, showing veins and hairs; E. Mature rachis internode and glumes (showing variation in size), viewed in plane of spikelet spread (with abaxial view of central glume in spikelet and largely side view of lateral glume); F. Spikelet, with lateral view of florets; G. Mature floret in abaxial view (left) and adaxial view (right); H. Cross-section of mature, indurate glume bases (showing range of size); I. Cross-section of central rachis internode.


cm
F2
mm
C
mm
D
B2
B1
cm
E
G
F1
dm
dm
A
H
mm
I

bluffs, P.O. Morrilton, 1500 ft, 3 Jul 1957, *D. Demaree 37234* (UARK, OKL, SMU); Logan Co., Magazine Mt., about 45 m east of Fort Smith, 8 Aug 1942, *D.M. Moore 420118* (TEX), Sep 1947, *D.M. Moore 470639/642* (UARK, NCU, US), and 30/31 Jul 1949, *D.M. Moore* 490422/441 (UARK) [awns slightly curving]; Montgomery Co., Camp Albert Pike on Little Missouri Rv., 30 Jun 1967, *G.E. Tucker* 5329 (NCU) [reddish brown ligules, auricles and nodes, leaves glabrous except sheath summit, blades glaucous, awns slightly to moderately curving]; Montgomery Co., road down from High Peak, Section 19, R24W T3S, 24 Jun 1970, *Mrs. Jim Miller 189* (UARK); Newton Co., Big Bluff above Buffalo Rv., 5 miles below Ponca, 5 Jun 1953, *D.M. Moore 53259* (UARK); Polk Co., Rich Mt., 1–15 miles northwest of Mena, *D.M. Moore 490521* (UARK, WIS) [leaves glabrous, spike internodes ca. 5 mm, glumes 15–18 mm, lemmas pubescent]; Polk Co., Wolf Pinnacle, 16 m north of Mena, 8 Sep 1954, *D.M. Moore 54267* (UARK); Sharp Co., Spring River banks, P.O. Hardy, 20 Jun 1948, *D. Demaree 26890A* (TEX) [glumes vestigial, awns straight, closer to *E. hystrix*]. MISSOURI: Christian Co., 3 miles west of Nixa, rocky wooded banks, 24 Jun 1954, *E.J. Palmer 57959* (SMU) [rachis internodes only 5–7 mm, anthers 2.5–3 mm]. OKLAHOMA: Le Flore Co., rocky woods, north side of Rich Mt. near Page, 8 Sep 1913, *G.L. Stephens s.n.* (MO, NCU) [awns slightly curving]; Le Flore Co., Rich Mt., roadside oak-pine dominant, 16 Jun 1940, *H. Taylor 110* (OKL); Le Flore Co., Winding Stair Mts., 5 miles from Hwy 271, 10 Jul 1967, J. & C. Taylor 4002 (SMU) [not glaucous, lemmas glabrous, with less curving awns—perhaps introgressed with *E. hystrix*]; Le Flore Co., new road in deciduous-conifer forest 10 miles E of Talihiua on S.H. 1, 27 Jun 1970, *R. Tyrl et al. 49* (OKL) [lemmas glabrous to hirsute]; Le Flore Co., Rich Mountain, stunted woods near overlook on State Hwy. 1, 18 Aug 1994, *J. Campbell s.n.* (KY).

Some other possible records of this taxon need further investigation. In Arkansas and Oklahoma, several additional populations have been reported in the Ouachitas by D. Zollner (Arkansas Nature Conservancy, pers. comm.), generally on base-rich soils. Under "*Elymus interruptus*" Steyermark (1963) cited the following collection from southwestern Missouri: Barry Co., rocky open woods near Viola, 26 Aug 1957, *E.J. Palmer 66416.* This collection has not yet been located at UMO or elsewhere, but it is likely to belong to the group described above.

Not listed above are several sympatric collections that appear closer to *Elymus hystrix* but still somewhat introgressed with these *svensonii*-like plants. Such plants differ from *E. hystrix* mainly in their more or less appressed spikelets and slightly curving awns. An example is from Arkansas: Baxter Co., bottoms above Norfold Dam, P.O. Ellis, 600 ft. elevation, 14 Jul 1942, D. Demaree 23533 (SMU). Also not included above are a few collections from this region that appear closer to *Elymus canadensis* but have more setaceous glumes than typical for that species. An example is from Arkansas: Polk Co., Rich Mountain, 1–15 m northwest of Mena, generally wooded, non-calcareous Mississippian sandstone, 1200–2800 ft., 31 Aug 1949, *D. Moore 490521* (UARK).

Steyermark (1963) cited two other collections under "*Elymus interruptus*" from well north of the Ozark and Ouachita plants. These are from Missouri: Gentry Co., *Steyermark 76299* (location unknown but FI needs further search); Lafayette Co., rocky wooded bluff along Missouri Rv., 1.5 miles northeast of Dover, 12 Jun 1953, *Palmer 55939* (UMO). These collections deserve further study, but their disjunction, plus Steyermark's note of "2–4 cm awns" and his figure, suggest that these plants

←

Figure 7. Ouachita-Ozark plants similar to *Elymus svensonii* (drawn from *Demaree 29337* unless noted). A. Habit; B. Upper portion of culm with mature spike, viewed on plane with alternating spread of spikelets (B2 from *Palmer 57957*); C. Sheath summit and blade bases; D. Adaxial leaf surface, showing veins and hairs; E. Mature rachis internodes and glumes (showing variation in of size), viewed in plane of spikelet spread (with abaxial view of central glume in spikelet and largely side view of lateral glume); F. Spikelet, with lateral view of florets (F2 from *Palmer 57957*); G. Mature floret in abaxial view (left) and adaxial view (right); H. Cross-sections of mature, indurate

may be closer to *E. diversiglumis*. Such affinity is supported by G. Yatskievych (Missouri Botanical Garden, pers. comm.) for *Palmer 55939*. Also, Bush (1926, p. 88) noted that "specimens collected in northeastern Missouri by Davis, were sent to Hitchcock for identification, who determined them as *E. diversiglumis,* but I have seen no specimens from anywhere near this state . . . ." These "Davis" specimens have not yet been relocated. Apart from these references, the closest records of *E. diversiglumis* to northern Missouri are in northern Iowa (Gabel 1984).

The plants described above appear to be closer to *Elymus svensonii* than to any other known taxon. They have only setaceous or vestigial glumes, in contrast to the generally broader, linear-setiform glumes of *E. interruptus*. Their characters overlap with *E. svensonii* although, on average, plants may differ as follows: lemmas usually pubescent (versus glabrous), with awns 20–30 mm (versus 10–20 mm); florets usually 3 (versus 4–5); rachis internodes usually 7–13 mm (versus 6–10 mm); leaves glabrous or pubescent (versus usually villous); and plants not as strongly glaucous. Until more intensive research is conducted, it seems best to treat these plants informally as another distinct entity that has probably resulted from independent hybridization between *E. canadensis* and *E. hystrix.*

ELYMUS HYSTRIX WITH CURVED AWNS OR APPRESSED SPIKELETS

As noted above, within the ranges of *Elymus diversiglumis, E. svensonii* and the similar Ozark-Ouachita plants there appear to be frequent introgressants between these plants and *E. hystrix.* Elsewhere, there are also scattered records of *E. hystrix* with curving awns and, in a few cases, appressed spikelets. Whether these plants represent occasional variation within the *E. hystrix* gene-pool, or whether they are outlying remnants of hybridization with *E. canadensis* or other introgressants, is currently unknown. It is likely that further study of their genetics, morphology and ecology will improve overall understanding of the *interruptus* group.

The following collections of *Elymus hystrix* have slightly to moderately curving awns, though in some cases it is possible that processing of the plant material may have induced apparent curvature. Where noted, spikelets are also somewhat appressed and glumes are somewhat developed, in contrast to typical plants.

Collections examined. U.S.A. ALABAMA: Jefferson Co., along Turkey Ck. off Old Narrows Rd. off Co. Rd. 131, roadside and creekbed, 1 Jun 1984, *J.P. Barber 607* (NCU). MARYLAND: Allegany Co., along Potomac River on south side of hill, 1 mile southwest of Rawlings, alluvial woods, 28 Jul 1967, *R.M. Downs 1384* (NCU) [spikelets appressed]; Washington Co., south slope facing Potomac River with [pines], oaks, hickories & redbud, at Pierre, 7 Jul 1967, *R.M. Downs 897* (NCU) [spikelets somewhat appressed, some glumes developed]; Washington, south slope on calcareous sandstone, mixed woods and alluvial woods, 1.5 miles south of Antietam, 19 Jul 1968, R.M. Downs 3465 (NCU) [spikelets somewhat appressed]. MISSOURI: Franklin Co., Pacific, 14 Jun 1879, leg. *H. Eggert s.n.* (MO); Jefferson Co., Walden, 8 Jul 1875, leg. *H. Eggert s.n.* (MO) [some glumes developed]. NEW YORK: [Yates Co.] Penn Yan, *Anon s.n.* (MO 2970626 ex S. Buckley herb.). NORTH CAROLINA: Mitchell Co., wooded creek bottom, 0.8 miles NE of Hawk, 16 Jul 1958, *H.A. Ahles 43273* (NCU); Yancey Co., thickets on creek bank 5.1 miles west of Ramseytown, 16 Jul 1958, *H.A. Ahles 46811* (NCU) [spikelets less widely spreading]. OHIO: Greene Co., Clifton Gorge, 5 Jul 1967, *L.D. Cribben 266* (OKL). VIRGINIA: Craig Co., 0.8 miles west of jct. Co. 606 & 612 on Co. 606, northeast of New Castle, 19 Jul 1967, *F.C. James 7610* (NCU) [some awns curving, others not]; Loudoun Co., northeast slope on Catoctin formation, basic lava flows, schist and gneiss, mixed, 4 miles north of Lucketts on Rt. 15, 2 Aug 1968, *R.M. Downs 4152* (NCU) [some awns curving, others not]. WEST VIRGINIA: Morgan Co., north slope on varicolored shales and sandstones, Brosins, jct. Co. rds. 1 & 2, 1 Jul 1968, *R.M. Downs 2731* (NCU) [spikelets appressed].

Most of these collections are from the Appalachian regions of North Carolina, Virginia, West Virginia, and Maryland. In the area with more northern records, R. Bargis (Maryland Nature Conservancy, pers. comm.) has observed several populations of *Elymus hystrix* with curving awns in or near the "shale bar-

rens" of Maryland and West Virginia. The shale barrens are famous for their xerophytic endemics and disjunct populations of western vascular plants. Like the xeric sites with *E. svensonii* or related plants in the Interior Low Plateaus and the Ozark-Ouachita region, this region lies slightly east of the main range of *E. canadensis.* However, it seems likely that *E. canadensis* has extended further east during drier climatic eras, and it is possible that there may still be remnants of introgression with *E. hystrix.*

DISCUSSION

Although there are many uncertainties in the inferred phylogenetic and biogeographic relationships for the various taxa outlined above, some general conclusions and suggestions are possible.

(1) Taxa of the *Elymus interruptus* group have usually been inadequately treated in floristic accounts and sometimes overlooked completely. There is a need for them to be more carefully incorporated into future accounts, but any treatment must remain tentative until more detailed genetic research is conducted.

(2) The taxa of this group mostly occupy relatively dry, open habitats in ranges that are disjunct from each other by hundreds of miles. If most of them have diverged from a common ancestral species, it would appear that the original species was once widespread but became reduced and fragmented. This may be unlikely, since there are no traces of such a species between the disjunct populations. The alternative view, that origins were largely independent, is favored here because of the likelihood that the western species, *E. canadensis,* expanded into the southeastern U.S.A. during drier climatic periods, allowing hybridization with *E. hystrix* or related species at several locations in the transition between forest and grassland. It is also possible that *E. hystrix* occurred further west during wetter climatic periods.

(3) The morphological differences between these entities are not great and generally involve details of awn length and curvature, rachis internode length, pubescence, and coloration. To some extent, these are the kinds of differences that might be expected to result from hybrids between different races of *E. canadensis* and *E. hystrix,* or their close relatives. For example, the northern *E. diversiglumis* has hirsute to strigose lemmas similar to the northern *E. canadensis* var. *canadensis,* whereas the southern *E. interruptus* has glabrous to marginally pubescent lemmas similar to the southern *E. canadensis* var. *brachystachys,* as noted by Church (1967).

(4) The least well-known plants in this group are *Elymus interruptus* (sensu stricto) of Texas, New Mexico, Arizona, and northern Mexico; *E. pringlei* of eastern Mexico; and the *pringlei*-like plants of southern Texas. We need further exploration and collection of these plants, including living material, before a thorough study can be made. It is also important to determine if there are disjunct occurrences of *E. hystrix,* or perhaps introgressed relics, within the isolated areas of relatively mesic forest in this region.

A continuing source of uncertainty for the hypothesis of independent hybridizations is lack of knowledge about past eastward extensions of *Elymus canadensis* and past westward extensions of *E. hystrix* or its relatives. And an underlying mystery is whether *E. hystrix* and its closest allies, globally, are remnants of a formerly more widespread North Temperate (Arcto-Tertiary) ancestral group. In western North America, the species that has traditionally been considered closest to *E. hystrix* is *E. californicus,* but this species has much larger anthers, more complex vestigial branching at rachis nodes, larger overall plant size, a doubled chromosome number ($2n = 56$), and apparent partial genomic affinity with the genus *Leymus* (Jensen and Wang 1997). In East Asia, some species treated in *Hystrix,* e.g., *H. coreana* (Honda) Ohwi, also appear morphologically close to *Leymus* spp. (Tsvelev 1983), but there are other species, e.g., the Sino-Himalayan *H. duthiei* (Stapf ex Hook.f.) Bor, that appear quite similar to *E. hystrix.* Nevertheless, Svitashev et al. (1997) could not match the genomes in either of these Asian species with genomes of better known taxa in *Leymus* or *Hystrix.*

It is unlikely that we will gain any definitive knowledge about past distributions of putative parental species in the foreseeable future. However, more intensive study of genomes and other molecular data may suggest phylogenetic relationships and geographic pathways

for past genetic exchanges and introgressions. Further morphological and distributional work may have limited value, but this paper, at least, has laid out a hypothesis for testing with new techniques in the future.

ACKNOWLEDGEMENTS

I thank the following people for their assistance and encouragement during the work for this paper: Mary Barkworth, Ralph Brooks, Hugh Iltis, Max Medley, Dan Nicholson, Rob Soreng, and George Yatskievych. I am also most grateful to the curators of the various herbaria where I have studied material or obtained loans.

LITERATURE CITED

Barkworth, M. E. 2000. Changing perceptions of the Triticeae. Pages 110–120. in: S. W. L. Jacobs and J. Everett (eds.). Proc. 3rd Int. Symp. on Gross Systematics and Evolution. CSIRO, Canberra, Australia.

Beetle, A. A. 1991. [*Elymus* in] Las Gramineas de Mexico. Tomo III:43–45. Secretaria de Agricultura y Recursos Hidraulicos, Cotecoca, Mexico City.

Buckley, S. B. 1862. [Descriptions of plants, No 3.] Proc. Acad. Nat. Sci. Philadelphia [14]:88–100.

Bush, B. F. 1926. The Missouri species of *Elymus*. Am. Midl. Naturalist 10:49–88.

Campbell, J. J. N. 2000. Notes on North American *Elymus* species (Poaceae) with paired spikelets: I. *E. macgregorii* sp. nov. and *E. glaucus* ssp. *mackenzii* comb. nov. J. Ky. Acad. Sci. 61:88–98.

Church, G. L. 1954. Interspecific hybridization in eastern *Elymus*. Rhodora 56:185–197.

Church, G. L. 1958. Artificial hybrids of *Elymus virginicus* with *E. canadensis, interruptus, riparius,* and *wiegandii*. Am. J. Bot. 45:410–417.

Church, G. L. 1967. Taxonomic and genetic relationships of eastern North American species of *Elymus* with setaceous glumes. Rhodora 69:121–162.

Cronquist, A. 1991. Manual of vascular plants of northeastern United States and adjacent Canada. New York Botanical Garden, Bronx, NY.

Delcourt, H. R., P. A. Delcourt, G. R. Wilkins, and E. N. Smith. 1986. Vegetational history of the Cedar Glade Regions of Tennessee, Kentucky, and Missouri during the past 30,000 years. Assoc.Southeast. Biol. Bull. 33: 128–137.

Fernald, M.E. 1950. Gray's manual of botany, 8th ed. American Book Company, New York, NY.

Gabel, M. 1984. A biosystemtic study of the genus *Elymus* (Gramineae: Triticeae) in Iowa. Proc. Iowa Acad. Sci. 91:140–146.

Hitchcock, A. S. 1935. Manual of the grasses of the United States. USDA Misc. Publ. No. 200, Washington, D.C.

Hitchcock, A. S., and A. Chase. 1951. Manual of the grasses of the United States. 2nd ed. USDA Misc. Publ. No. 200, Washington, D.C.

Holmgren, P. K., N. H. Holmgren, and L. C. Barnett. 1990. Index herbariorum. Part I: The herbaria of the world. International Association for Plant Taxonomy, New York Botanical Garden, Bronx, New York.

Jensen, K. B., and R. R.-C. Wang. 1997. Cytological and molecular evidence for transferring *Elymus coreanus* from the genus *Elymus* to *Leymus* and molecular evidence for *E. californicus* (Poaceae:Triticeae). Int. J. Plant Sci. 158:872–877.

Medley, M. E. 1993. An annotated catalog of the known or reported vascular flora of Kentucky. Ph.D. dissertation, University of Louisville, Louisville, KY.

Scribner, F. L., and C. R. Ball. 1901. Studies on American grasses. III. Miscellaneous notes and descriptions of new species. USDA Div. Agrostol. Bull. 24:39–50.

Scribner, F. L., and E. R. Merrill. 1901. Studies on American grasses. I. Some recent collections of Mexican grasses. USDA, Div. Agrostol. Bull. 24:1–30.

Smith, E. B. 1991. An atlas and annotated list of the vascular plants of Arkansas, 2nd ed. Published by the author, University of Arkansas, Fayetteville.

Steyermark, J. A. 1963. Flora of Missouri. Iowa State University Press, Ames, Iowa.

Svitashev, S., T. Bryngelsson, X-M. Li, and R. R-C. Wang. 1997. Genome-specific repetitive DNA and RAPD markers for genome identification in *Elymus* and *Hordelymus*. Paper 4 in Ph.D. Dissertation by S. Svitashev, Swedish University of Agricultural Sciences, Svalöv, Sweden.

Tsvelev, N. N. 1983. Grasses of the Soviet Union. Parts I and II. [Translated from Russian; published for the Smithsonian Institution and National Science Foundation.] Amerind Publishing Co. Pvt. Ltd., New Delhi.

Yatskievych, G. 1999. Steyermark's flora of Missouri, Vol. 1. Missouri Botanical Garden Press, St. Louis, MO.

J. Ky. Acad. Sci. 63(1):39–46. 2002.

Notes on North American *Elymus* Species (Poaceae) with Paired Spikelets. III. A Synoptic Key

Julian J. N. Campbell

The Nature Conservancy (Kentucky Chapter), 642 W. Main Street, Lexington, Kentucky 40508

ABSTRACT

A synoptic key to all North American *Elymus* species that typically have paired spikelets (or occasionally 3–5 per node) is presented, including *Hystrix* and *Sitanion* but excluding *Leymus.* Based on a survey of the literature and examination of many herbarium collections, 20 species are recognized (including the introduced *E. dahuricus*). There is continuing uncertainty about the delimitation of some species. It is suggested that this group of species may be largely natural, but there has probably been considerable reticulate evolution between this group and others, and within this group, confounding simple ideas of divergence. Because the morphology of these plants offers relatively little substance for clear taxonomic distinctions, it is advisable to consider several characters in each couplet and to be aware of potential hybrids. Hypothetical relationships between species will need to be tested with molecular methods in the future.

INTRODUCTION

Elymus L. (Poaceae: Triticeae) has been a difficult genus to understand in North America. The genus itself has been defined in different ways and, even within the strictly defined "core" groups of species, there have been continuing problems in recognition and delimitation of taxa. The key presented below is being developed as part of a new Manual of North American Grasses (M. E. Barkworth, K. M. Kapels, and L. A. Vorobik, in preparation). While attempting to draw on all current morphological data to reflect probable phylogenetic relationships wherever possible, this treatment must still be considered just a hypothetical base from which to examine the problem eventually with molecular methods. Because of the relatively simple form of the *Elymus* plant and the plastic nature of its morphological characters, there is limited value in classifications derived only from the optical microscope, naked eye, and human brain.

Issues of generic definition and the genomic evidence for realignment of traditional generic concepts are not dealt with here. The species included below, those typically with paired spikelets, are retained by most current authorities within *Elymus,* including *Hystrix* Moench and *Sitanion* Raf. (e.g., Barkworth 1992, 1997). It is generally accepted that *E. arenarius* L. and allied species with relatively large (cross-pollinating) anthers, short awns, narrow glumes, and rhizomes can be more reasonably assigned to the genus *Leymus* Hochst.

Within North American *Elymus* species, there appears to be a reasonable separation between those that typically have paired spikelets versus those that typically have single spikelets. In the former group, spikelets are occasionally single at lower or upper nodes and (especially in robust plants) there are sometimes 3–5 spikelets per node. In the latter group, spikelets are occasionally paired at lower nodes. Some authors (e.g., Löve 1984) have assigned species with paired spikelets to *Elymus* sect. *Elymus, E.* sect. *Hystrix* (Moench) A. Löve, and *E.* sect. *Sitanion* (Raf.) A. Löve. This group (except *Sitanion*) is more diverse in eastern than in western North America. Species with single spikelets, formerly treated in *Agropyron* L., have been assigned to *E.* sect. *Goulardia* (Husn.) Tzvelev, and *E.* sect. *Elytrigia* (Desv.) Melderis (including the alien *E. repens* (L.) Gould and its relatives). This group is more diverse in western than in eastern North America. However, these sectional concepts have not been widely applied in North America.

The group with single spikelets includes many with awnless glumes and lemmas, whereas there is only one virtually awnless taxon in the group with paired spikelets, *E. submuticus* (Hook.) Smyth. Those with single spikelets also include many rhizomatous species, whereas none of those with paired spikelets are clearly rhizomatous, except perhaps the "shortly rhizomatous" *E. californicus* (Bol. ex Thurb.) Gould, which is an anomalous species with high chromosome number.

Although this division into groups with paired versus single spikelets may be largely "natural" in a phylogenetic sense, there probably has been some hybridization and introgression between the groups—the Triticeae appear to be riddled with reticulate evolution (Barkworth 1997; Cronquist et al. 1977; Stebbins and Snyder 1956). There is occasional morphological overlap between these two groups of species. In particular, although *E. glaucus* Buckley typically has paired spikelets, there is a need to allow for some *E. glaucus* with predominantly single spikelets (M. Barkworth, pers. comm.). The latter plants may be easily confused with *E. trachycaulus* (Link) Gould ex Shinners (syn. *Agropyron trachycaulum* (Link) Malte).

Before 1953, treatments of these species were provided by Booher & Tryon (1948), Bush (1926), Fernald (1933, 1950), Gleason (1952), Hitchcock (1935), Hitchcock and Chase (1951), Rydberg (1932), Wiegand (1918), and others. There was much inconsistency between the keys in these treatments along with continuing problems in lack of recognition of some species and varieties or in excessive splitting of others. After 1953, more intensive studies of particular species groups or geographic areas were provided by Bowden (1964), Brooks (1974; and Brooks in McGregor et al. 1986), Church (1954, 1958, 1967a, 1967b), Cronquist et al. (1977), Davies (1980), Gabel (1984), and others. However, the results of these studies have still not been thoroughly synthesized and incorporated into modern regional treatments (e.g., Cronquist 1991) and modern state floras (e.g., Yatskievych 1999).

The key below is based on an examination of all relevant literature and of specimens at several herbaria, including GH, KANU, KY, ISC, MADI, MAINE, MO, NCU, OKL, SMU, TENN, TEX, UARK, US, UTC, VDB, WIS (Holmgren et al. 1990). It is designed to suggest the natural relationships among species that are indicated by morphological characters, limited as they are, but it must be emphasized that there has not yet been significant definitive research into genetic relationships. It is also important to note that there are occasional hybrids and intermediate forms; thus, one should consider more than just one or two characters at each step. In general, there is no single, reliable "key character" for each couplet, although glumes are often the most useful feature on which to focus. A future work (J.J.N. Campbell in preparation) will include details of all subspecies and varieties in North America, together with descriptions, illustrations, and distribution maps.

The following assumptions can be made in this key: "Glaucous" generally implies that a bluish waxy (pruinose) bloom occurs on the plant, but this often can be rubbed off to reveal deep green beneath. Unless stated otherwise, dimensions of plant parts refer to length. Dimensional ranges reflect variation from depauperate to robust individuals, but with unusual extremes noted in parantheses (generally, <1% of collections examined). Rachis internodes refer to central spike positions; lower internodes can be much longer in some taxa. Spike length and width include the awns but, unless noted, lengths of spikelets, glumes, and lemmas exclude the awns. Awn curvature often is variable, becoming more pronounced with dryness and maturity of the spikelet. Widths of lanceolate to linear glumes are measured at the widest point, but those with tapering linear to setaceous glumes are measured about 5 mm above the base. Lemma sizes refer to the lowest 2–3 florets, excluding any terminal reduced florets, but floret numbers per spikelet given in parentheses include such "rudiments". Typical anthesis dates refer to central sections of the species' range. These may be a month earlier or later at southern or northern extremes.

SYNOPTIC KEY TO NORTH AMERICAN *ELYMUS* SPECIES WITH PAIRED SPIKELETS

1. Rachis disarticulating at maturity; glumes, including awns, 30–110 mm long, setaceous, often divided, outcurving from near the base; lowest lemmas sometimes sterile; anthers 0.9–2.2 mm long; blades 1–6 mm wide, often pubescent on both sides; culms 8–65 cm long, often puberulent [*Elymus* sect. *Sitanion* (Raf.) A. Löve]

2. Glumes entire or bifid; lemma awns about 0.4 mm wide at the base; rachis internodes 3–10 (15) mm long .... *E. elymoides* (Raf.) Swezey
   [syn. *Sitanion hystrix* (Nutt.) J.G. Sm.]; with several described subspecies; widespread in western North America, from northern Mexico and British Columbia to the western Great Plains (and occasionally adventive further east).
2. Glumes 3–9-divided; lemma awns about 0.2 mm wide at the base; rachis internodes 3–5 (8) mm long .... *E. multisetus* (J.G. Sm.) Burtt Davy
   [Univ. Calif. Publ. Bot. 1:57 (1902); not M.E. Jones (1912)]; from eastern Washington and Idaho to southern California and northwestern Arizona.

1. Rachis not disarticulating; glumes, including awns, 0–40 mm long, linear-lanceolate, setaceous or subulate, entire, straight or outcurving from well above the base; lowest lemmas fertile; anthers 0.9–5 mm long; blades (2) 4–18 (28) mm wide, pubescent above or glabrous; culms 30–220 cm long, glabrous.
   3. Glumes, including awns, either both 0–3 mm long and subulate, or 1–20 mm long and often differing in length by more than 5 mm, 0.1–0.6 mm wide, tapering from the base, with 0–1 distinct vein (excluding thickened margins), persistent; rachis internodes slender (4–12 mm long and ca. 0.1–0.5 mm thick at the thinnest section), often with green bands down the sides [*Elymus* sect. *Hystrix* (Moench) A. Löve].
      4. Anthers 6–8 mm; lemmas 10–15 mm, scabrous to hispid; glumes vestigial (0–1 mm); paleas acute; spikelets 2–4 (5) per node, the lower ones often pedicellate; blades 6–28 mm wide; ligules 1–5 mm long .... *E. californicus* (Bol. ex Thurb.) Gould
         [syn. *Hystrix californica* (Bol. Ex Thurb.) Kuntze]; endemic to coniferous forests near the coast in western California, from Sonoma County to Santa Cruz County.
      4. Anthers 2–5 (6) mm long; lemmas 7–12 mm, glabrous or pubescent; glumes vestigial or developed; paleas obtuse; spikelets 2 per node, subsessile; blades 4–17 mm wide; ligules usually 1–2 mm long; plants from the Rocky Mountains and further east.
         5. Spikelets widely spreading to horizontal; lemma awns straight (rarely somewhat curving); glumes 0–3 mm long, with no distinct veins (rarely one glume to 20 mm long, 0.2 mm wide); spikes usually erect .... *E. hystrix* L.
            [syn. *Hystrix patula* Moench]; with var. *bigelovianus* (Fern.) Bowden; throughout temperate eastern North America (west to Oklahoma and Manitoba), except the southeastern Coastal Plain.
         5. Spikelets appressed; lemma awns straight or curving; glumes sometimes absent, but usually 1–20 mm long, 0.1–0.6 mm wide, with vein(s) distinct; spikes erect or nodding [note that hybrids between *E. hystrix* and other species can be common in some cases, and will often key out here, but the following taxa appear to have more extensive populations and generally deserve species status.]
            6. Lemma awns outcurving; glumes usually unequal (differing by more than 5 mm) when developed, but sometimes both absent; spike more or less nodding [northern and eastern taxa probably resulting from hybridization of *E. hystrix* and *E. canadensis* or closely related species].
               7. Lemmas hirsute to strigose, the awns 20–35 mm long; rachis internodes 4–6 mm long; sheaths glabrous; plants green to moderately glaucous .... *E. diversiglumis* Scribn. & C.R. Ball;
                  in the northern Great Plains, from Saskatchewan and Wyoming to Ontario and Wisconsin, and rarely south to Michigan, Iowa and probably Missouri.
               7. Lemmas glabrous or pubescent, the awns 10–20 mm long; rachis

internodes 6–13 mm long; sheaths glabrous to villous; plants usually glaucous, often strongly so.

8. Lemmas typically glabrous, with awns ca. 10–20 mm, strongly curving; spikelets with (3) 4–5 florets; rachis internodes ca. 6–10 mm long; leaves usually villous; plants strongly glaucous . . . . *E. svensonii* G.L. Church; limestone bluffs in or near the Central Basin of Tennessee, and the Bluegrass region of Kentucky.

8. Lemmas typically pubescent, with awns ca. 20–30 mm, slightly curving; spikelets with ca. 3 florets; rachis internodes ca. 7–13 mm long; leaves glabrous or pubescent; plants not strongly glaucous . . . . unnamed plants resembling *E. svensonii* [informally described by Campbell (2002)]; in the central Ouachita Mountains and western Ozark Mountains of Arkansas, Oklahoma, and Missouri.

6. Lemma awns straight to slightly curving; glumes well developed, subequal; spike erect or slightly nodding [southwestern plants greatly disjunct from typical *E. hystrix*].

9. Anthers 4.5–6 mm long; lemmas glabrous; spikelets 25–40 mm long, with 5–8 florets (including rudiments); spike 9–20 cm long, the internodes (5) 7–15 (22) mm long, glabrous on back; blades often densely short-pilose . . unnamed plants resembling *E. pringlei* [initially considered a variant of *E. interruptus* Buckley but with erect spike, larger spikelets, narrower glumes, and less curving awns (Campbell 2002)]; on the Edwards Plateau in southern Texas.

9. Anthers 2.5–4 mm long; lemmas usually scabrous-hispid to strigose-pubescent; spikelets 18–25 mm long, with 3–5 (6) florets; spike 4–12 cm long, the internodes 3–6 mm long (strongly tapering), hispid on back; blades thinly scabrid to pilose . . . . *E. pringlei* Scribn. & Merr. [some unusually narrow-glumed *E. interruptus* may key out here but can be distinguished by: lemmas glabrous to scabrid, the awn often outcurving; rachis internodes 5–14 mm long; blades often densely short-pilose]; at 1500–2250 m in the Sierra Madre Oriental of eastern Mexico (Coahuila, Nuevo León, Hidalgo, Veracruz).

3. Glumes, including awns, 10–40 mm long, usually differing in length by less than 5 mm, 0.2–2.3 mm wide, linear-lanceolate to setaceous, usually widest above the base, with 2–8 veins, persistent or disarticulating; rachis internodes slender (as above) or stout (2–5 mm long and ca. 0.5–1 mm thick at the thinnest section), generally without distinct green bands down the sides (except *E. interruptus*) [*Elymus* sect. *Elymus*].

10. Glume bases flat, thin, and evidently veined, or indurate (with veins hidden) for less than 1 mm, the bodies more or less equalling the ca. 11–15 mm lowest lemmas (and the generally equal acute paleas); lemma awns usually outcurving and spikes nodding to pendent (except *E. glaucus*), the internodes 4–12 mm long (or to 2 mm in some *E. canadensis*).

11. Glumes with hyaline margins, the awns 1–10 mm long; spikelets 1–3 per node, appressed to slightly spreading, sometimes purplish; cauline nodes mostly exposed; short rhizomes or stolons often produced.

12. Anthers 0.9–1.7 mm long; lowest lemmas 3–6 mm longer than the 3–8 mm glumes, usually scabrous, the awns usually outcurving;

spikelets usually with 4–5 florets; spikes 2–5 cm wide, pendent; cauline nodes glabrous . . . . *E. sibiricus* L.; widespread in cool temperate regions of central and eastern Asia; reported since 1950 in North America, from southern Alaska through northern British Columbia to the southwestern District of Mackenzie.

12. Anthers 1.5–4.5 mm long; lowest lemmas 0–2.5 mm longer than the 6–14 mm glumes, glabrous to hirsute, the awns straight or outcurving; spikelets usually with 2–4 florets; spikes 0.5–2.5 mm wide, erect to nodding, or slightly pendent; cauline nodes occasionally puberulent.
    13. Glumes (4.5) 6–10 (11) mm long; lemmas 7–12 mm long, scabrous to hirsute, especially near margins, the awns usually outcurving.
        14. Lemmas scabrous or hispid, but without much longer marginal hairs; spikes erect to slightly nodding; leaves usually pale and somewhat glaucous . . . . *E. dahuricus* Turcz. ex Griseb.; widespread in temperate central and east Asia; introduced for reclamation in some parts of western North America.
        14. Lemmas hirsute on the lateral veins and on the margins above the middle, the longest hairs scattered near the margins; spikes nodding to slightly pendent; leaves usually deep green . . . . *E. hirsutus* J. Presl; along the coastal mountains from the Aleutian Islands to northern California.
    13. Glumes (6) 9–14 (19) mm long; lemmas 8–16 mm long, glabrous to scabrous or short hirsute, the awns usually straight or flexuous . . . . *E. glaucus* Buckley; see Campbell (2000) for key to subspecies; widespread in western North America from Baja California and New Mexico to Alaska and Saskatchewan; sporadic in the northern Great Plains to the western Great Lakes region from Illinois to upper Michigan, sometimes appearing transitional to *E. trachycaulus* (Link) Gould ex Shinners; also disjunct on rocky sites in the Ozark and Ouachita mountains, as subsp. *mackenzii* (Bush) J.J.N. Campbell.

11. Glumes without hyaline margins, the awns 5–27 mm long; spikelets 2–4 per node, spreading, rarely purplish; cauline nodes mostly covered (except *E. interruptus*); rhizomes or stolons rarely produced.
    15. Spikes erect to slightly nodding, the internodes 5–14 mm long, ca. 0.2–0.3 mm thick (at narrowest section), without abaxial angles; glumes 0.2–0.5 (0.7) mm wide; lemmas 7–10 mm long, glabrous to occasionally pubescent at margins; the awns 15–22 mm long, straight to moderately outcurving; blades 3–9 mm wide; culms 50–100 cm long, the nodes mostly exposed . . . . *E. interruptus* Buckley [some *E. pringlei* may key out here, but see above under 9]; in Coahuila (northeastern Mexico), Arizona, New Mexico, and western Texas.
    15. Spikes usually nodding to pendent, the internodes 2–8 (12) mm long, ca. 0.3–1 mm thick, often with abaxial angles; glumes 0.3–1.6 mm wide; lemmas 8–15 mm long, glabrous to uniformly pu-

bescent, the awns 15–40 (50) mm long, moderately to strongly outcurving; blades 4–24 mm wide; culms 60–180 cm long, the nodes mostly covered.

16. Glumes 0.5–1.6 mm wide; lemma awns 15–40 (50) mm long; paleas acute; rachis internodes 2–5 (7) mm long; blades (3) 4–15 (20) mm wide, pale green, usually glabrous or scabridulous above . . . . *E. canadensis* L.; divisible into var. *canadensis*, var. *brachystachys* (Scribn. & C.R. Ball) Farw., and var. *robustus* (Scribn. & J.G. Sm.) Mack. & Bush; throughout most of temperate North America, being especially common in the Great Plains, but rare in California and virtually absent south of Arkansas to New Jersey.

16. Glumes 0.3–0.8 mm wide; lemma awns 15–25 (35) mm long; paleas narrowly truncate; rachis internodes 5–8 (12) mm long; blades 8–24 mm wide, dark green, usually thinly pilose above . . . . *E. wiegandii* Fern.; including forma *calvescens* Fern.; from Wyoming and Saskatchewan to Massachusetts and Nova Scotia.

10. Glume bases terete, indurate, and lacking evident veins for 0.5–4 mm, the bodies (unless indistinct from awns) generally exceeding the ca. 9–13 mm lowest lemmas (and the generally shorter obtuse paleas); lemma awns straight; spikes erect or nodding, the internodes 2–5 mm long (or to 7 mm in *E. macgregorii*).

17. Glumes persistent, 0.2–1 mm wide, with 2–4 veins, the basal 0.5–2 mm straight or nearly so; lemmas rarely glabrous; spikelets with 1–3 (4) florets; spikes nodding, exserted.

18. Blades glabrous to scabrous, pale dull green; spikes 7–25 cm long, the internodes usually 3–5 mm long; spikelets with 2–3 (4) florets; lemmas usually scabrous, 7–14 mm long, 1–5 mm longer than the acute paleas; flowering usually in late June to late July . . . . *E. riparius* Wieg.; widespread in most of temperate east-central North America; rare in southeastern Canada (Ontario and Québec) and the eastern Great Plains (Kansas and Nebraska); virtually absent on the southeastern Coastal Plain.

18. Blades villous to pilose, dark glossy green, spikes 4–12 cm long, the internodes usually 2–3 mm long; spikelets with 1–2(3) florets; lemmas usually villous, 5.5–9 mm long, 0–1.5 mm longer than the obtuse paleas; flowering usually in early June to early July . . . . *E. villosus* Muhl.; with var. *arkansanus* (Scribn. & C.R. Ball) J.J.N. Campbell; common from the eastern Great Plains (Oklahoma to North Dakota) to the east coast (Virginia to Massachusetts); rare in the eastern Rockies (Arizona to Wyoming) and southeastern Canada (Ontario to Newfoundland), and absent from the southeastern Coastal Plain.

17. Glumes disarticulating with the lowest floret, 0.7–2.3 mm wide, with (2) 3–5 (8) veins, the basal 1–4 mm clearly bowed out; lemmas often glabrous; spikelets with (2) 3–5 (6) florets.

19. Spikes 0.7–2 cm wide including awns, exserted or sheathed; lemma awns 1–15 (20) mm long; spikelets appressed to slightly spreading; blades usually glabrous to scabridulous.

20. Lemma awns 1–3 (5) mm long; blades often ascending, somewhat involute, those higher on the stiffly erect culms broader and more persistent; flowering usually in early June to mid-August .... *E. submuticus* (Hook.) Smyth [perhaps better treated as a subspecies of *E. virginicus,* including forma *lasiolepis* Fern.]; extending from Washington and British Columbia, through the Intermountain region and northern Rockies, to the northern Great Plains, but becoming infrequent or rare in the midwest, the Great Lakes region, and the northeast (Pennsylvania to Québec); virtually unknown in the southeast (beyond Oklahoma and western Kentucky).

20. Lemma awns 5–15 (20) mm long; blades usually spreading or lax, not markedly broader or more persistent towards the culm summit; flowering usually in mid-June to late July .... *E. virginicus* L.; with vars. *intermedius* (Vasey ex A. Gray) Bush, *halophilus* (E.P. Bicknell) Wieg., and *jejunus* (Ramaley) Bush; widespread across temperate North America as far west as Arizona and Alberta, but infrequent to rare in the Rocky Mountains, western Great Plains, and southeastern Coastal Plain.

19. Spikes 2.5–6 cm wide, exserted; lemma awns 15–40 mm long; spikelets spreading; blades glabrous or villous.

21. Spikes with 15–30 nodes, the internodes 3–5 mm long; blades lax or ascending and involute, generally pale dull green; auricles 0–2 mm long, brownish at maturity; flowering usually in mid-June to late July .... *E. glabriflorus* (Vasey ex L.H. Dewey) Scribn. & Ball; with var. *australis* (Scribn. & C.R. Ball) J.J.N. Campbell; in most of the southeastern United States, extending north to Iowa, Indiana, West Virginia, and Massachussetts.

21. Spikes with 9–18 nodes, the internodes 4–7 mm long; blades lax (and often broader), generally with much glaucous-pruinose bloom but glossy green beneath; auricles 2–3 mm long, typically purplish-black at maturity; flowering usually in mid-May to mid-June .... *E. macgregorii* R. Brooks & J.J.N. Campbell; most frequent in the central Mississippi and Ohio river watersheds (from South Dakota and Ohio to Texas and Alabama), but also extending to the Piedmont and the northeast (North Carolina to Maine), and onto the Edwards Plateau (south-central Texas).

ACKNOWLEDGMENTS

I thank the following people for their assistance and encouragement during the work for this paper: Mary Barkworth, Ralph Brooks, Hugh Iltis, Max Medley, Dan Nicholson, and Rob Soreng. I am also most grateful to the curators of the various herbaria where I have studied material or obtained loans.

LITERATURE CITED

Barkworth, M. E. 1992. Taxonomy of the Triticeae; a historical perspective. Hereditas 116:1–14.

Barkworth, M. E. 1997. Taxonomic and nomenclatural comments on the Triticeae in North America. Phytologia 83:302–311.

Booher, L. E., and R. M. Tryon. 1948. A study of *Elymus* in Minnesota. Rhodora 50:80–91.

Bowden, W. M. 1964. Cytotaxonomy of the species and interspecific hybrids of the genus *Elymus* in Canada and neighboring areas. Canad. J. Bot. 42:547–601.

Brooks, R. E. 1974. Intraspecific variation in *Elymus virginicus* (Gramineae) in the central United States. M.A. thesis, University of Kansas, Lawrence, KS.

Bush, B. F. 1926. The Missouri species of *Elymus*. Am. Midl. Naturalist 10:49–88.

Campbell, J. J. N. 2000. Notes on North American *Elymus* species (Poaceae) with paired spikelets. I. *E. macgregorii* sp. nov. and *E. glaucus* ssp. *mackenzii* comb. nov. J. Ky. Acd. Sci. 61:88–98.

Campbell, J. J. N. 2002. Notes on North American *Elymus* species (Poaceae) with paired spikelets. II. The *interruptus* group. J. Ky. Acad. Sci. 63:xx–xx.

Church, G. L. 1954. Interspecific hybridization in eastern *Elymus*. Rhodora 56:185–197.

Church, G. L. 1958. Artificial hybrids of *Elymus virginicus* with *E. canadensis, interruptus, riparius,* and *wiegandii.* Am. J. Bot. 45:410–417.

Church, G. L. 1967a. Taxonomic and genetic relationships of eastern North American species of *Elymus* with setaceous glumes. Rhodora 69:121–162.

Church, G. L. 1967b. Pine Hills *Elymus*. Rhodora 69:330–345.

Cronquist, A., A. H. Holmgren, N. H. Holmgren, J. L. Reveal, and P. K. Holmgren. 1977. Intermountain flora. Vascular plants of the Intermountain West, U.S.A. Columbia Univ. Press, New York, NY.

Cronquist, A. 1991. Manual of vascular plants of northeastern United States and adjacent Canada. New York Botanical Garden, Bronx, NY.

Davis, R. S. 1980. Introgression between *Elymus canadensis* and *E. virginicus* L. (Triticeae, Poaceae) in south central United States. Ph.D. dissertation, Texas A&M University, College Station, TX.

Fernald, M. L. 1933. Types of some American species of *Elymus*. Rhodora 35:187–198.

Fernald, M. L. 1950. Gray's manual of botany, 8th ed. American Book Company, New York, NY.

Gabel, M. 1984. A biosystematic study of the genus *Elymus* (Gramineae: Triticeae) in Iowa. Proc. Iowa Acad. Sci. 91:140–146.

Gleason, H. A. 1952. The New Britton and Brown illustrated flora of the Northeastern United States and adjacent Canada, Vol. 1. Hafner Press, New York, NY.

Hichcock, A. S. 1935. Manual of the grasses of the United States. U.S. D.A. Misc. Publ. 200.

Hitchcock, A. S., and A. Chase. 1951. Manual of the grasses of the United States. U.S.D.A. Misc. Publ. 200, 2nd ed.

Holmgren, P. K., N. H. Holmgren, and L. C. Barnett. 1990. Index herbariorum. Part I: the herbaria of the xworld. International Association for Plant Taxonomy, New York Botanical Garden, Bronx, NY.

Löve, A. 1984. Conspectus of the Triticeae. Feddes Repert. 95:425–521.

McGregor, R. L., T. M. Barkley, R. E. Brooks, and E. K. Schofield. 1986. Flora of the Great Plains. Univ. Press of Kansas, Lawrence, KS.

Rydberg, P. A. 1932. Flora of the prairies and plains of central North America. New York Botanical Garden, Bronx, NY.

Stebbins, G. L., and L. A. Snyder. 1956. Artificial and natural hybrids in the Gramineae, Tribe Hordeae. IX. Hybrids between western and eastern North American species. Am. J. Bot. 43:305–312.

Wiegand, K. M. 1918. Some species and varieties of *Elymus* in eastern North America. Rhodora 20:81–90.

Yatskievych, G. 1999. Steyermark's flora of Missouri, vol. 1. Missouri Botanical Garden Press, St. Louis, MO.

J. Ky. Acad. Sci. 63(1):47–51. 2002.

Notes on North American *Elymus* Species (Poaceae) with Paired Spikelets. IV. A Key to the Species and Varieties in Kentucky

Julian J. N. Campbell

The Nature Conservancy (Kentucky Chapter), 642 W Main Street, Lexington, Kentucky 40508

ABSTRACT

A key to Kentucky *Elymus* species and varieties with paired spikelets and a map of county distribution of these taxa are presented.

INTRODUCTION

This fourth and final paper in a series on *Elymus* taxa with paired spikelets presents a key to the species and varieties in Kentucky. It is modified from the general key to North American species (Campbell, 2002) by simplifying couplets to focus just on Kentucky taxa and adding details of varieties. A map of known county records is included. However, due to considerable hybridization and other problems, more intensive work is needed to fully evaluate the distinction and status of some taxa, especially at the intraspecific level. (See Campbell, 2002, for notes on key characters, discussion of taxonomic problems, and citation of relevant literature.)

KEY TO KENTUCKY *ELYMUS* SPECIES AND VARIETIES WITH PAIRED SPIKELETS

Figure 1 shows county records for individual taxa. Brief habitat notes on each taxon are included within the key.

1. Rachis disarticulating at maturity; glumes, including awns, 30–110 mm long, setaceous, often divided, outcurving from near the base; lowest lemmas sometimes sterile; anthers 0.9–2.2 mm long; blades 1–6 mm wide, often pubescent on both sides; culms 8–65 cm long, often puberulent . . . . *E. elymoides* (Raf.) Swezey
   Native of areas west of Kentucky; probably not native in the state, but apparently a rare waif along roads; our plants are ssp. *elymoides*. [syn. *Sitanion hystrix* (Nutt.) J.G. Sm.]
1. Rachis not disarticulating; glumes, including awns, 0–40 mm long, linear-lanceolate, setaceous or subulate, entire, straight or outcurving from well above the base; lowest lemmas fertile; anthers 0.9–5 mm long; blades (2) 4–18 (28) mm wide, pubescent above or glabrous; culms 30–220 cm long, glabrous.
   2. Glumes, including awns, either both 0–3 mm long and subulate or 1–20 mm long and often differing in length by more than 5 mm, 0.1–0.6 mm wide, tapering from the base, with 0–1 distinct vein (excluding thickened margins), persistent; rachis internodes slender (4–12 mm long and ca. 0.1–0.5 mm thick at the thinnest section), often with green bands down the sides.
      3. Spikelets widely spreading to horizontal; lemma awns straight (rarely slightly curving); glumes 0–3 mm long, with no distinct veins (rarely one glume to 20 mm long, 0.2 mm wide); spikes usually erect; plants usually not glaucous-pruinose . . . . *E. hystrix* L.
         [syn. *Hystrix patula* Moench]; abundant on dry to moist soils in open woods and thickets, especially on base-rich slopes and small stream terraces.
         3.1. Lemmas glabrous to scabrous . . . . var. *hystrix*.
         3.1. Lemmas pubescent . . . . var. *bigelovianus* (Fern.) Bowden
            infrequent and perhaps restricted to a few central and western regions of the state.
      3. Spikelets appressed; lemma awns outcurving (when dried); glumes sometimes

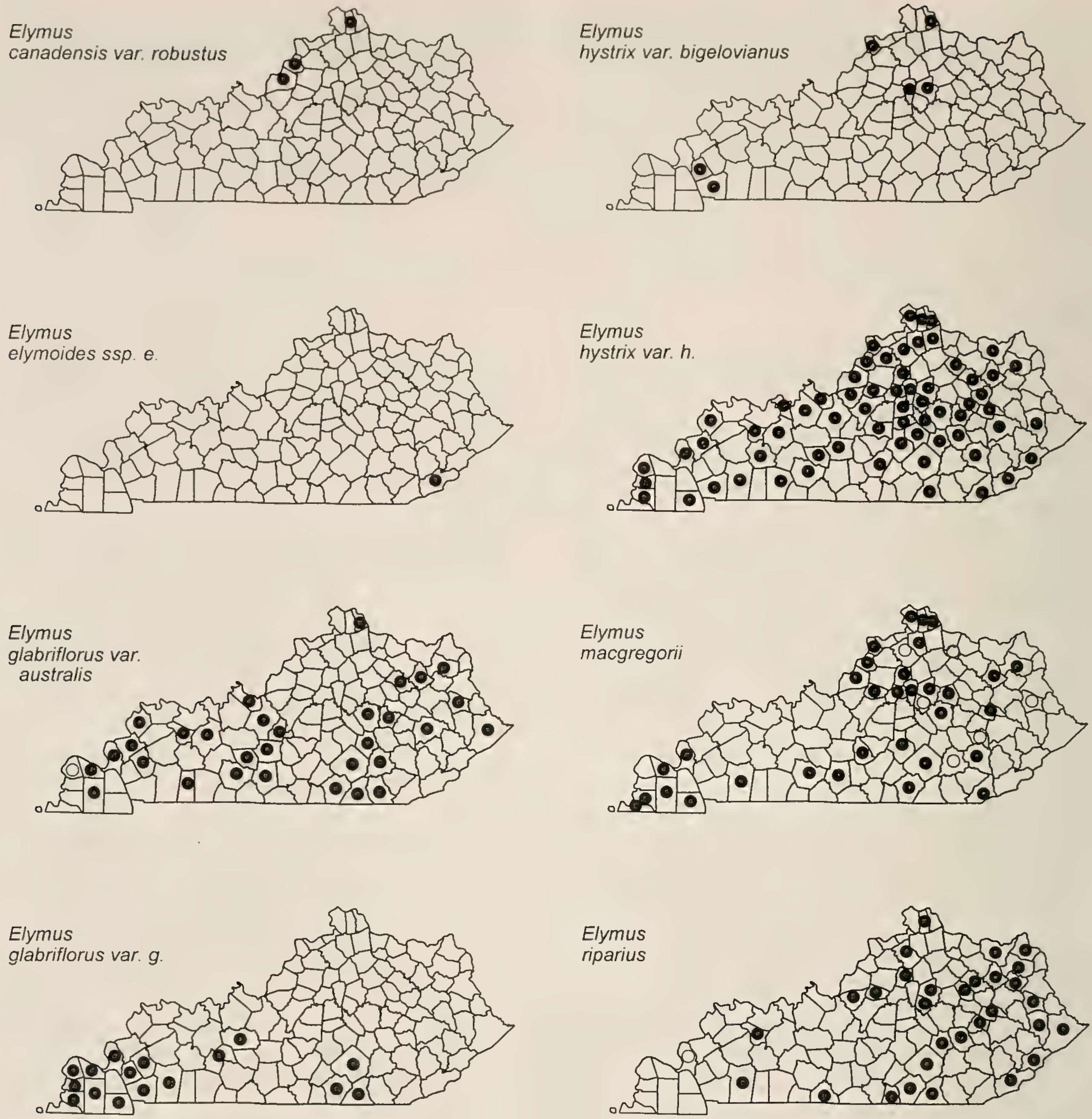


Figure 1. Maps showing county records of *Elymus* taxa with paired spikelets in Kentucky. Data are mostly from herbaria in Kentucky; details are available from the author. Open dots are atypical collections or other uncertain records.

absent, but usually 1–20 mm long, unequal, 0.1–0.6 mm wide, with a distinct vein; spikes more or less nodding; plants strongly glaucous-pruinose .... *E. svensonii* G.L. Church

locally abundant but restricted to dry, rocky soils in open forests on Ordovician limestone bluffs along the Kentucky River (and its tributaries) in the Inner Bluegrass region of Kentucky, and to a few other localities.

2\. Glumes, including awns, 10–40 mm long, usually differing in length by less than 5 mm, 0.2–2.3 mm wide, linear-lanceolate to setaceous, usually widest above the base, with 2–8 veins, persistent or disarticulating; rachis internodes slender (as above) or stout (2–5 mm long and ca. 0.5–1 mm thick at the thinnest section), generally without distinct green bands down the sides.

4\. Glume bases flat, thin, and evidently veined or indurate (with veins hidden) for

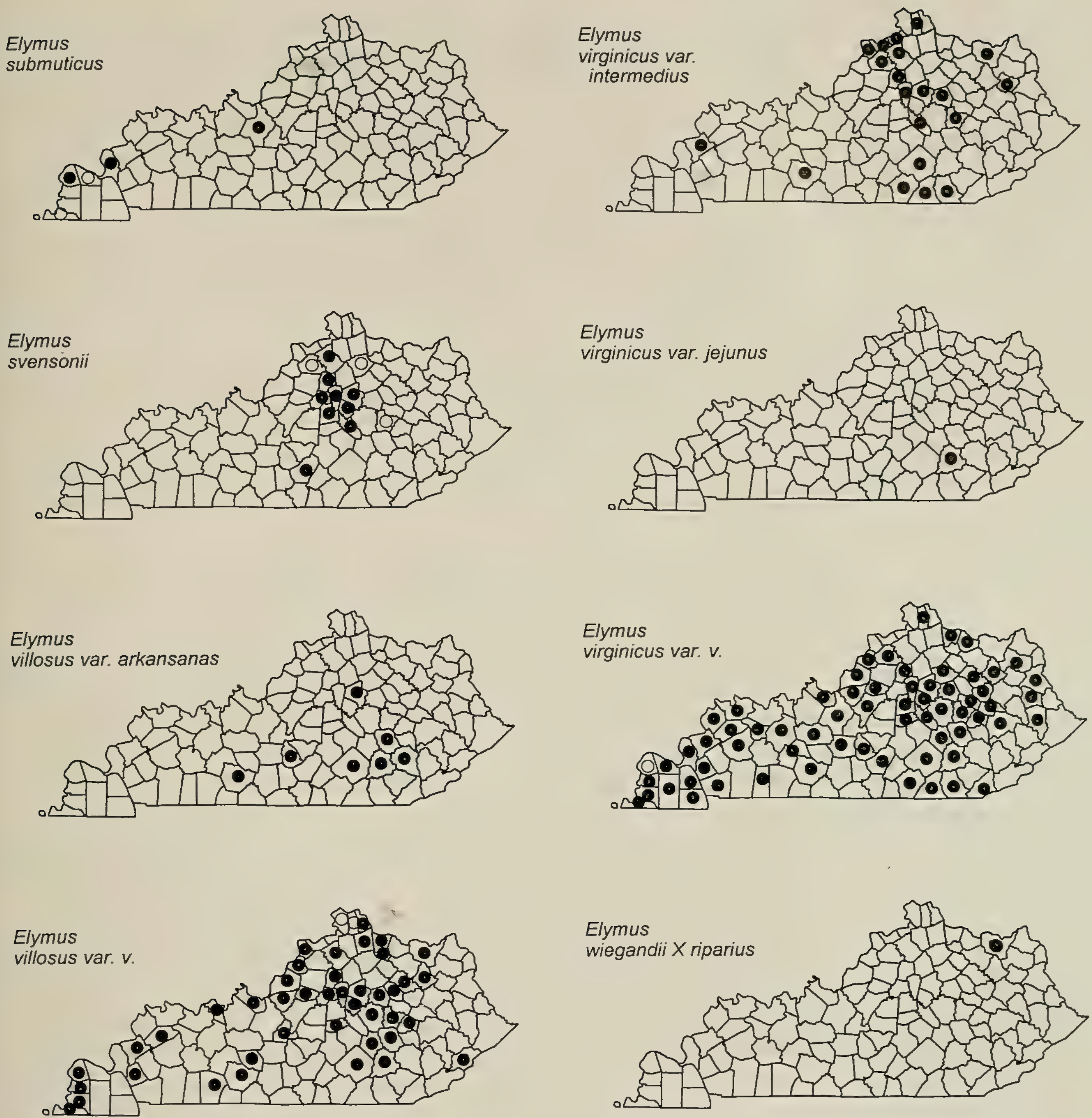


Figure 1. Continued.

less than 1 mm, the bodies more or less equalling the ca. 11–15 mm lowest lemmas (and the generally equal acute paleas); lemma awns moderately to strongly outcurving; spikes nodding to pendent, internodes (2) 4–8 (12) mm long.

5. Glumes 0.5–1.6 mm wide; lemma awns 15–40 (50) mm long; paleas acute; rachis internodes 2–5 (7) mm long; blades (3) 4–15 (20) mm wide, pale green, usually glabrous or scabridulous above . . . . *E. canadensis* L.

   endangered or locally extinct (not recorded in Kentucky since 1950); dry to moist or damp, often sandy or gravelly soil on prairies, dunes, stream banks, ditches, roadsides, and disturbed ground, or, especially to the south, in thickets and open woods near streams; our plants are probably referable to var. *robustus* (Scribn. & J.G. Sm.) Mack. & Bush [with spikes 15–25 (30) cm,

slightly nodding or almost erect, the internodes mostly 3–4 mm long, not strongly glaucous (often becoming yellowish or pale reddish brown); glumes often slightly indurate and bowed out at the base, the awn 15–25 mm long; lemma awns 30–40 mm long].

5. Glumes 0.3–0.8 mm wide; lemma awns 15–25 (35) mm long; paleas narrowly truncate; rachis internodes 5–8 (12) mm long; blades 8–24 mm wide, dark green, usually thinly pilose above . . . . *E. wiegandii* Fern.
expected on moist or damp, rich, alluvial soil, especially on sandy river terraces, in woods and thickets; the only Kentucky record is based on an atypical collection, possibly hybridized with *E. riparius* (R. Thompson, pers. comm.).

4. Glume bases terete, indurate, and lacking evident veins for 0.5–4 mm, the bodies (unless indistinct from awns) generally exceeding the ca. 9–13 mm lowest lemmas (and the generally shorter obtuse paleas); lemma awns straight; spikes erect or nodding, the internodes 2–5 mm long (or to 7 mm in *E. macgregorii*).

6. Glumes persistent, 0.2–1 mm wide, with 2–4 veins, the basal 0.5–2 mm straight or nearly so; lemmas rarely glabrous; spikelets with 1–3 (4) florets; spikes nodding, exserted.

7. Blades glabrous to scabrous, pale dull green; spikes 7–25 cm long, the internodes usually 3–5 mm long; spikelets with 2–3 (4) florets; lemmas usually scabrous, 7–14 mm long, 1–5 mm longer than the acute paleas; flowering usually in late June to late July . . . . *E. riparius* Wieg.
locally abundant on moist soils, especially sandy alluvium, in woods and thickets along larger streams, occasionally along upland ditches.

7. Blades villous to pilose, dark glossy green, spikes 4–12 cm long, the internodes usually 2–3 mm long; spikelets with 1–2 (3) florets; lemmas usually villous, 5.5–9 mm long, 0–1.5 mm longer than the obtuse paleas; flowering usually in early June to early July . . . . *E. villosus* Muhl.
abundant on moist to moderately dry, often rocky soils in woods and thickets, especially in calcareous or other base-rich soils, but also common on drier sandy soils or damper alluvial soils to the west and north.

7.1. Spikes pubescent . . . . var. *villosus*

7.1. Spikes glabrous to scabrous (except for the ciliate rachis margins) . . . . var. *arkansanus* (Scribn. & C.R. Ball) J.J.N. Campbell
generally rare, or perhaps more frequent in some hilly regions.

6. Glumes disarticulating with the lowest floret, 0.7–2.3 mm wide, with (2) 3–5 (8) veins, the basal 1–4 mm clearly bowed out; lemmas often glabrous; spikelets with (2) 3–5 (6) florets.

8. Spikes 0.7–2 cm wide including awns, exserted or sheathed; lemma awns 1–15 (20) mm long; spikelets appressed to slightly spreading; blades usually glabrous to scabridulous.

9. Lemma awns 1–3 (5) mm long; blades often ascending, somewhat involute, those higher on the stiffly erect culms broader and more persistent; flowering usually in early June to mid-August . . . . *E. submuticus* (Hook.) Smyth
[perhaps better treated as subspecies of *E. virginicus*]; rare on moist or damp soils of open forests, thickets, grasslands, ditches, and disturbed ground, especially on bottomland in western regions.

9. Lemma awns 5–15 (20) mm long; blades usually spreading or lax,

not markedly broader or more persistent towards the culm summit; flowering usually in mid-June to late July .... *E. virginicus* L. and varieties

9.1. Spikes glaucous, hispidulous to villous-hirsute, often intermediate in exsertion; glumes indurate in the lowest 1–2 mm; ligules and auricles usually vestigial; flowering usually in early July to mid-August .. var. *intermedius* (Vasey ex A. Gray) Bush
locally abundant but generally restricted to moist, base-rich soil in open forests and thickets on rocky, gravelly, or sandy banks of larger streams; also expected in prairies and fields of western regions.

9.1. Spikes green or glaucous, usually glabrous to scabrous; ligules and auricles usually evident (except perhaps for ligules in var. *jejunus*); flowering usually in mid-June to mid-July.

9.2. Spikes partly sheathed; glumes 1–2.3 mm wide, strongly indurate and bowed-out in the lowest 2–4 mm; plants usually green to yellowish brown; nodes mostly covered .... var. *virginicus*
abundant on moist to damp or rather dry soil, mostly on bottomland or fertile uplands, in open woods, thickets, or weedy sites.

9.2. Spikes usually exserted; glumes (0.5) 0.7–1.5 (1.8) mm wide, moderately indurate and bowed-out in the lowest 1–2 mm; plants usually glaucous-pruinose, sometimes reddish brown at maturity; nodes often exposed .... var. *jejunus* (Ramaley) Bush
very rare, perhaps not genetically distinct in the state; expected on moist to dry soil (sometimes alkaline or saline), in open, rocky, or alluvial woods, grasslands, glades, and disturbed places.

8. Spikes 2.5–6 cm wide, exserted; lemma awns 15–40 mm long; spikelets spreading; blades glabrous or villous.

10. Spikes with 15–30 nodes, the internodes 3–5 mm long; blades lax or ascending and involute, generally pale dull green; auricles 0–2 mm long, brownish at maturity; flowering usually in mid-June to late July .... *E. glabriflorus* (Vasey ex L.H. Dewey) Scribn. & Ball and varieties
locally abundant on moist, damp, or dry soil in open woods, thickets, and tall grasslands, sometimes weedy; absent from the Bluegrass region and perhaps other northern areas.

10.1. Spikelets (and usually foliage) glabrous to scabrous; spikes usually 9–16 cm long; lemmas 7–13 mm long .... var. *glabriflorus*
generally restricted to relatively moist or damp soil of bottomland and upland depressions in southern regions.

10.1. Spikelets (and usually foliage) pubescent; spikes usually 6–12 cm long; lemmas 6–10 cm long .... var. *australis* (Scribn. & Ball) J.J.N. Campbell
widespread on relatively dry, infertile soil, especially in hilly regions.

10. Spikes with 9–18 nodes, the internodes 4–7 mm long; blades lax, generally with much glaucous-pruinose bloom but glossy green be-

neath; auricles 2–3 mm long, blackish at maturity; flowering usually in mid-May to mid-June .... *E. macgregorii* R. Brooks & J.J.N. Campbell

locally abundant on moist, deep, alluvial and other base-rich soil in woods and thickets, especially in the Bluegrass region.

LITERATURE CITED

Campbell, J. N. N. 2002. Notes on North American *Elymus* species (Poaceae) with paired spikelets. III. A synoptic key. J. Ky. Acad. Sci. 63:39—46.

J. Ky. Acad. Sci. 63(1):53–64. 2002.

Vascular Flora of the Henderson Fork Road Surface-mined Area, Bell County, Kentucky

Barbara L. Rafaill and Ralph L. Thompson

Department of Biological Sciences, Georgetown College, Georgetown, Kentucky 40324 and Department of Biology, Berea College, Berea, Kentucky 40404

ABSTRACT

From 1986–2001, we conducted a descriptive study of the vascular flora on the 38-year-old Henderson Fork Road Surface-mined Area in Bell County, Kentucky. This 3.4 ha area had been contour mined for coal between 1962 and 1963 and then hand-planted with *Robinia pseudoacacia* and seeded with a mixture of *Festuca elatior* and *Lespedeza cuneata.* We delineated seven habitats from the original highwall, bench, and outslope topographic positions created during mining. Our annotated list of vascular plants comprises 312 species in 201 genera from 82 families. Forty-one species (13%) are non-native. Taxa consist of Equisetophyta (1), Lycopodophyta (1), Polypodiophyta (10), Pinophyta (2), and Magnoliophyta (298). The most important families in species richness are Asteraceae (55), Poaceae (36), Cyperaceae (16), Fabaceae (15), and Rosaceae (13). Sørensen's Index of Similarity is a coefficient of 0.747 between the flora of Henderson Fork Road Surface-mined Area and a nearby larger prelaw coal-mined area. Species richness of the surface-mined area is comparable to that expected on unmined areas of the same size in the Mixed Mesophytic Forest Region.

INTRODUCTION

The Surface Mine Control and Reclamation Act of 1977 (SMCRA), or Public Law 95-87, was enacted to ensure that land surface-mined for coal was reclaimed to their original contours and planted with a 90% herbaceous vegetation cover to control erosion and stimulate productivity. Prior to that time in Kentucky, some efforts were made to reclaim coal surface mines. During the 1980s and 1990s, studies were conducted on the flora and vegetation of five pre-SMCRA mines that had been reclaimed between 1963 and 1975 in the Appalachian Plateaus Physiographic Province of Kentucky. The vascular flora of four of these surface-mined areas has been described: Lily in Laurel County (Thompson et al. 1984); Trace Branch in Rockcastle County (Thompson and Wade 1991); Log Mountain in Bell County (Thompson et al. 1996); and Fonde in Bell County (Wade and Thompson 1999). These four areas developed vegetation characterized by diverse plant communities with high species richness. Furthermore, these prelaw mine sites provided new habitats not found in the contiguous unmined areas or postlaw surface-mined areas.

This paper documents the flora and plant associations of the fifth reclaimed pre-SMCRA site, the Henderson Fork Road Surface-mined Area, a 38-year-old contour coal mine in Bell County, Kentucky. The objectives of our study are to: 1) document the vascular flora with representative herbarium vouchers; 2) describe the habitats, plant associations, and successional trends; and 3) compile an annotated list with origin of taxon, habitats, and relative abundance.

THE STUDY AREA

The Henderson Fork Road Surface-mined Area (HFR) is located on a W-SW mountain slope 20 km northwest of Middlesboro, Kentucky, in southwestern Bell County, at latitude 36° 38′ 21″ N and longitude 83° 51′ 34″ W near the junction of Kentucky Highways 74 and 3485 (Henderson Fork Road).

HFR is a 3.4 ha contour coal-mined site located within the Log Mountains of the Cumberland Mountain Section of the Appalachian Plateaus Province of Fenneman (1938). It is situated on a mid-slope position at ca. 686 m in elevation. HFR occurs on the Hignite Coal Bed at the base of the Hignite Formation in contact with the underlying Catron Formation of the Pennsylvanian System. The Hignite Formation is a sequence of interbedded siltstone, sandstone, claystone, and coal (Rice and Maughan 1978).

Forest soils of ridges and 2–70% slopes in the Log Mountains that have been surface mined for coal are classified as the Fairpoint and Bethesda soil series. These mixed soils are

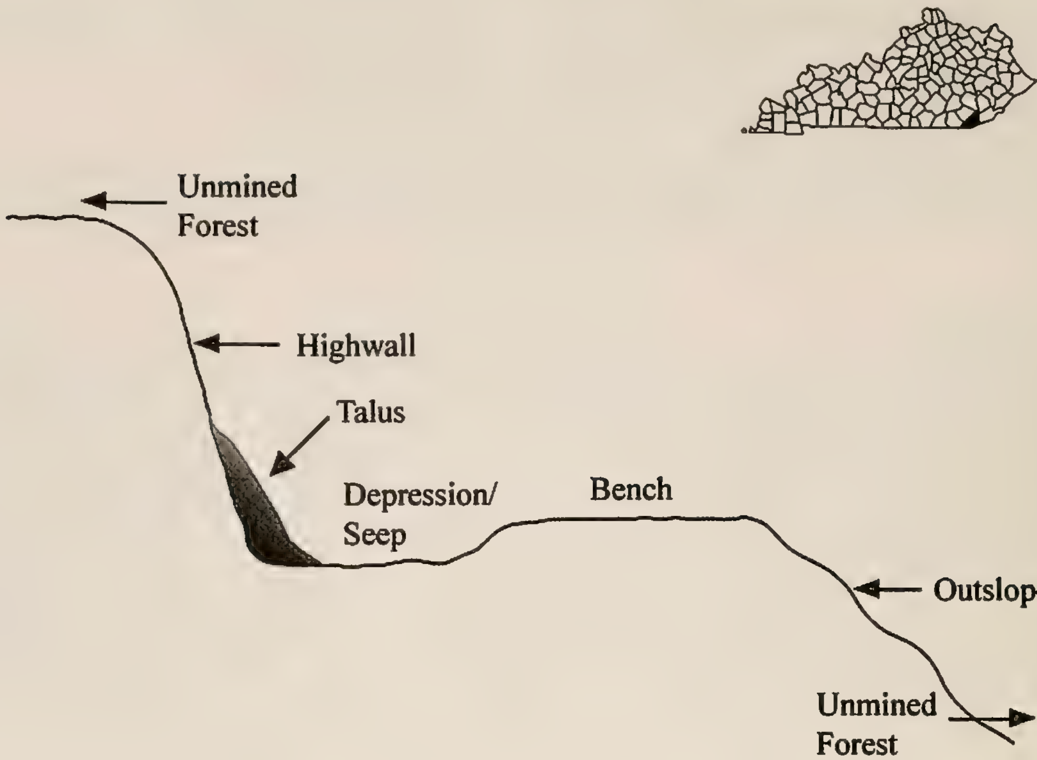


Figure 1. Configuration of the Henderson Fork Road Surface-mined Area ca. 38 years post-mining, Bell County, Kentucky.

typically acid to non-acid loamy-skeletal, very deep, well-drained, and moderately permeable Typic Udorthents (Childress 1992). A study of the outslope soils at HFR after the first 20 years showed a pH range of 4.6–4.9 in the top 30 cm, organic matter between 1.29 and 1.68%, and the beginning of soil profile development (Rafaill 1988).

The climate in the vicinity of the study site is classified as temperate humid continental with warm summers, cool winters, and abundant or adequate precipitation in all seasons (Trewartha 1968). However, periodic droughts do occur and often contribute to problems with fire. At the Middlesboro Weather Station during the 1961–1990 period, the mean annual precipitation was 130 cm including a mean snowfall of 37 cm. Mean annual temperature was 13.3°C with a mean summer maximum of 23°C and a mean winter minimum of −4°C. The mean growing season was 170 days based on 0°C (University of Kentucky Agricultural Weather Center 1995).

The forests of upper slopes and ridgecrests in the Log Mountains are described as the All Deciduous Mixed Mesophytic Community Type of the Mixed Mesophytic Forest Region by Braun (1950). This complex vegetation type is characterized by several important canopy species sharing dominance. Küchler (1964) mapped this region within the Mixed Mesophytic *(Acer-Aesculus-Fagus-Liriodendron-Quercus-Tilia)* Forest.

During 1962–1963, the study site area was contour mined for coal, which created the highwall, bench, and outslope topographic positions typical of prelaw mining (Figure 1). To facilitate revegetation for erosion control and nitrogen-fixation, the entire mine was seeded with a mixture of *Festuca elatior* and *Lespedeza cuneata* and hand-planted with *Robinia pseudoacacia* seedlings. This grass and legume combination was the standard reclamation mix used in the early-to-mid 1960s in the eastern United States (Vogel 1981). Although the mine received no postmining fertilizer or lime treatment, a well-established herbaceous cover of grass and legumes developed with good survival of *Robinia pseudoacacia.* By 1983, the HFR outslope supported saplings typical of the Mixed Mesophytic Forest Region, e.g., *Acer rubrum, Liriodendron tulipifera, Quercus rubra, Oxydendrum arboreum,* and *Robinia pseudoacacia* (Rafaill 1988).

METHODS

We conducted an intensive floristic survey of the entire Henderson Fork Road Surface-

Table 1. Classification of vascular plants at Henderson Fork Road Surface-mined Area.

Division	Family	Genera	Species	Native	Exotic	Species composition percent
Lycopodiophyta	1	1	1	1	0	0.3
Equisetophyta	1	1	1	1	0	0.3
Polypodiophyta	4	8	10	10	0	3.2
Pinophyta	2	2	2	2	0	0.6
Magnoliophyta	74	189	298	257	41	95.6
Magnoliopsida	63	148	224	194	30	71.8
Liliopsida	11	41	74	63	11	23.7
Total:	82	201	312	271	41	100.0

mined Area during the growing seasons of 1988 and 1989. Collecting trips were also made in 1986, 1987, 1993, 1996, and 2001. Voucher specimens were processed and deposited in the Berea College Herbarium (BEREA). References used for identification were Gleason and Cronquist (1991) and Strausbaugh and Core (1978). Classification and nomenclature follow Gleason and Cronquist (1991).

An annotated species list was compiled from field collections and includes origin of taxon (native or exotic), codes for habitats and relative abundance, and a representative voucher specimen number.

Species similarity between the 38-year-old HFR site and a comparable 25-year-old coal surface mine in Bell County, the Log Mountain Surface-mined Demonstration Area, was determined using Sørensen's Index of Similarity after Mueller-Dombois and Ellenberg (1974).

Species richness was determined from the species-area curve, $S = 272A^{0.113}$ where S is the number of species and A is the area in hectares (Wade and Thompson 1991). This compares the number of species expected in unmined areas of the same size within the Mixed and Western Mesophytic Forest Regions to those actually found at HFR.

Plant associations are plant communities with uniform habitat conditions, a characteristic physiognomy, and a definite floristic composition. Through plant collections and field survey work, we defined associations at HFR based on the existing surface-mined habitats, forest physiognomy, and the relative abundance of the characteristic trees, shrubs, woody vines, and herbs. Taxa are given in order of relative abundance in the section on Habitats and Associations.

RESULTS AND DISCUSSION

Floristic Analysis

We documented 312 species representing 201 genera in 82 families at HFR (Table 1). These taxa are comprised of 298 Magnoliophyta (74 Liliopsida, 224 Magnoliopsida), 2 Pinophyta, 10 Polypodiophyta, 1 Equisetophyta, and 1 Lycopodiophyta. Of these taxa, 271 (87%) were native and 41 (13%) were exotic (Table 1). The most important families in terms of species richness were Asteraceae (55), Poaceae (36), Cyperaceae (16), Fabaceae (15), and Rosaceae (13). These five families correspond to the five largest families for Kentucky as reported by Browne and Athey (1992). The most common genera represented were *Carex* (10) followed by *Aster, Solidago,* and *Panicum* (8 each). A special concern species in Kentucky, *Gentiana decora* (KSNPC 2000), was documented on the bench habitat.

Floristic Similarity

Sørensen's Index of Similarity was calculated for a comparison of the flora between HFR and a 25-year-old pre-SMCRA coal-mined area, the Log Mountain Surface-mined Demonstration Area (LMDA), a 14.2 ha contour mine at ca. 900 m located 1.2 km away. The Sørensen's Index of Similarity is 0.747 with 251 species common to the two sites. This significant coefficient would have been even higher if certain features between the two sites were more comparable, e.g., the younger LMDA had 24% greater surface area, 24 surviving planted reclamation species, 74 exotic

Table 2. Species-area relationships on five pre-SMCRA coal surface-mined areas in Kentucky.[1]

Surface-mined area	Area (ha)	Number known species	Number predicted species[2]	Percent deviation
Henderson Fork Road	3.4	312	312	−0.0
Log Mountain	14.2	360	367	−1.9
Lily	14.0	350	367	−4.6
Trace Branch	2.5	272	302	−9.9
Fonde	7.3	298	340	−12.6

[1] Modified from Wade and Thompson (1993).
[2] Based on a species-area prediction equation for the combined Mixed and Western Mesophytic Forest Regions (Wade and Thompson 1991).

species, and a total of 360 species overall (Thompson et al. 1996).

Species Richness

A predicted species richness for an unmined contiguous area was 312 species using the species-area curve (Wade and Thompson 1991). Actual species richness at HFR was 312 taxa, and thus, relative species richness (the actual number of species divided by the expected number of species) was 100% or precisely what was predicted by the species-area curve. Therefore, HFR is the most floristically rich of the five inventoried pre-SMCRA surface-mined areas in eastern Kentucky and is comparable to contiguous unmined land (Table 2).

Rare Species

The discovery of *Gentiana decora* at HFR is important because it is classified as a "special concern species" in Kentucky by the KSNPC (2000). One or more species currently on the 2000 Kentucky list of endangered, threatened, or special concern species have been found at each of the four previously studied pre-SMCRA surface-mined areas (Thompson et al. 1984; Thompson and MacGregor 1986; Thompson and Wade 1991; Thompson et al. 1996; Wade and Thompson 1993). None of these rare species were found in adjacent unmined areas during initial or subsequent floristic reconnaissances. Pre-SMCRA surface-mined areas have provided unique disturbed habitats as "refugia" where rare species have become established (Thompson and Wade 1991; Thompson et al. 1996).

Habitats and Associations

The highwall, bench, and outslope were the three initial topographic positions created by surface mining at HFR. Each of the positions has developed varying habitats which now support distinctive plant associations (plant communities) of trees, shrubs, woody vines, and herbs.

Highwall. A 5–8 m contour highwall is contiguous to the bench and parallel to the outslope for the entire length of the mined area (Figure 1). The highwall ranges from a 90° slope to less than 45° as a result of erosion and subsequent talus accumulation. Two highwall habitats were identified, xeric eroded highwall and mesic eroded highwall.

The xeric eroded highwall is an open area characterized by severe soil erosion and exposed sandstone strata. This habitat supports the *Acer-Oxydendrum-Danthonia* Association. Diagnostic trees are *Acer rubrum, Liriodendron tulipifera, Oxydendrum arboreum,* and *Nyssa sylvatica. Rubus allegheniensis, Rhus copallinum, Vaccinium corymbosum, Smilax rotundifolia,* and *Toxicodendron radicians* are found in the shrub and woody vine layer. Indicator herbs are *Danthonia compressa, Andropogon virginicus, Panicum lanuginosum, Aristida dichotoma, Aster paternus, Coreopsis major, Solidago arguta, Lysimachia quadrifolia, Campanula divaricata,* and *Lespedeza intermedia.*

The mesic eroded highwall constitutes the majority of the overall highwall. The more shaded, moist conditions of this habitat have promoted establishment of characteristic perennial species of the Mixed Mesophytic Forest. The *Acer-Liriodendron-Hydrangea-Microstegium* Association is characteristic of this habitat. Diagnostic canopy trees are *Acer rubrum, Liriodendron tulipifera, Acer saccharum, Nyssa sylvatica, Fraxinus americana, Quercus rubra,* and *Q. prinus.* Indicator shrubs and woody vines are *Hydrangea arborescens, Clematis virginiana, Sambucus canadensis, Toxi-*

codendron radicans, and *Parthenocissus quinquefolia.* The naturalized *Microstegium vimineum* is the predominant herb of the mesic highwall. Other characteristic herbs include *Impatiens pallida, Eupatorium rugosum, Laportea canadensis, Cryptotaenia canadensis, Sanicula canadensis, Viola* spp., *Solidago caesia,* and *Carex* spp. More fern species are found on the mesic highwall than in any other habitat. Ferns include *Polystichum acrostichoides, Thelypteris hexagonoptera, T. noveboracensis,* and *Botrychium virginianum.*

Bench. A bench was formed when minesoils dredged from the steep mountain to expose the coal were pushed onto the mixed mesophytic forest below (Figure 1). The existing partially-leveled bench varies from 10 m to over 30 m at the widest point. It possesses the greatest species richness at HFR. All bench areas are well covered by vegetation except for ruts created from recent 4-wheel traffic along the old coal haul road. The bench currently supports a mixture of mostly native and some exotic species. The seeded *Festuca elatior* and *Lespedeza cuneata* have clearly declined over time through plant succession. The four bench habitats are xeric open, mesic shaded, standing water depressions, and seasonally wet seeps.

The xeric open bench is similar to the xeric, eroded highwall habitat. In the small sites where it occurs, it interrupts the more extensive mesic shaded bench habitat. Perennial herbs are dominant and a closed canopy has not yet developed. The *Panicum-Solidago-Lespedeza* Association characterizes this habitat. Volunteer trees include *Acer rubrum, Liriodendron tulipifera, Nyssa sylvatica,* and *Oxydendrum arboreum. Rubus allegheniensis* is the preeminent shrub and *Toxicodendron radicans* and *Smilax glauca* are representative woody vines. During spring and summer, perennial herbs are *Danthonia compressa, Festuca elatior, Dactylis glomerata, Panicum lanuginosum, Potentilla simplex,* and *Fragaria virginiana.* Late summer and fall flora are dominated by the Asteraceae, Poaceae, and Fabaceae. Indicator species include *Solidago nemoralis, S. rugosa, S. bicolor, Andropogon virginicus, Agrostis perennans, Lespedeza cuneata, L. intermedia,* and *Desmodium paniculatum. Lycopodium digitatum* and *Asplenium platyneuron* are present at the junction of the bench and outslope.

The mesic shaded bench occupies most of the length of the bench, and where it occurs, is continuous from the mesic highwall to the mesic outslope. The *Acer-Liriodendron-Microstegium* Association is dominant here. Important trees are *Acer rubrum, Liriodendron tulipifera, Acer saccharum, Cornus florida,* and *Robinia pseudoacacia.* Other invading trees include *Aesculus flava, Fraxinus americana, Cercis canadensis,* and *Prunus serotina.* A characteristic woody vine, *Clematis virginiana,* is interspersed with *Toxicodendron radicans, Parthenocissus quinquefolia,* and *Vitis aestivalis.* Indicator herbs include *Microstegium vimineum, Elymus hystrix, Ambrosia trifida, Impatiens pallida, Aster divaricatus, A. cordifolius, Eupatorium rugosum, Solidago flexicaulis,* and *Laportea canadensis.* A single colony of *Aplectrum hyemale* was found in one small area.

The standing water depressions occur on low bench areas of open pits and low depressions created from mining (Figure 1). Many wetland species are present in these seasonal to permanent wetland areas which support the *Salix-Typha-Carex* Association. *Salix nigra* and *S. sericea* found along narrow woody borders in these locations are dying out from progression of secondary succession. *Sambucus canadensis, Hydrangea arborescens, Clematis virginiana,* and *Toxicodendron radicans* are typical shrubs and woody vines present. Important species are *Typha latifolia, Carex prasina, Scirpus cyperinus,* and *Juncus effusus.* Other characteristic wetland species include *Leersia orzyoides, Microstegium vimineum, Rumex obtusifolius, Ludwigia alternifolia, Epilobium coloratum, Eupatorium fistulosum, Prunella vulgaris,* and *Polygonum* spp. In 1988 this habitat was quite dense with plants but, by 1996, spacing between plants was evident from shading effects.

The seasonally wet seeps is the most extensive of the two wetland types. These areas are the result of seepage from the highwall which flows onto the bench. This seepage either creates seasonally wet seep meadows or simply drains as narrow channels onto the outslope. Wetland seeps support the herbaceous *Impatiens-Equisetum-Leersia* Association. In the spring, *Equisetum arvense* forms almost solid

stands and is interspersed with *Impatiens pallida*, *I. capensis*, *Carex prasina*, *Glyceria striata*, and *Leersia orzyoides*. Other characteristic species are *Carex lurida*, *Scirpus polyphyllus*, *Juncus effusus*, *Panicum clandestinum*, and *Microstegium vimineum*. In the summer and fall, *Ludwigia alternifolia*, *Eupatorium fistulosum*, *E. perfoliatum*, *Mimulus ringens*, *Polygonum sagittatum*, and *Lobelia siphilitica* are representative species. *Sambucus canadensis*, *Hydrangea arborescens*, and *Clematis virginiana* are interspersed among the wetland herbs. *Gentiana decora* accompanied by *Spiranthes cernua*, *Habernaria clavellata*, *Chelone glabra*, and *Woodwardia areolata* were only found at the border of one seep.

Outslope. The outslope was formed when minesoil overburden from the bench was pushed onto the steep forested terrain below. The current outslope ranges from 30 to 60 m from the edge of the bench down to the bottom (Figure 1). Several tree species survived partial burial by mine overburden, but most of the existing vegetation developed from seed rain and the seed bank intermixed within the original minesoils.

The mesic outslope occupies the greatest surface area at HFR, and the *Acer-Liriodendron-Microstegium-Aster* Association is the most extensive plant association. *Robinia pseudoacacia* originally planted on the outslope is being shaded out by the canopy. Important volunteer trees are *Acer rubrum*, *Liriodendron tulipifera*, *Fraxinus americana*, *Acer saccharum*, *Oxydendrum arboreum*, *Nyssa sylvatica*, *Cornus florida*, *Magnolia acuminata*, and *Aesculus flava*. Characteristic shrubs and woody vines include *Clematis virginiana*, *Toxicodendron radicans*, *Parthenocissus quinquefolia*, *Vitis aestivalis*, *Smilax rotundifolia*, and *Rubus allegheniensis*. Surface fire burned parts of the outslope and bench between 1987 and 1988. Woody plants were scorched and stem die-back occurred, while herbaceous species were burned back to ground level. Currently, forest vegetation shows little evidence of negative effects from fire.

Herbaceous species on the outslope are floristically rich in the spring and fall. Spring indicator herbs include *Anemonella thalictroides*, *Viola palmata*, *V. canadensis*, *Carex* spp., *Sedum ternatum*, *Geranium maculatum*, *Erythronium americanum*, *Trillium erectum*, *T. grandiflorum*, and *Polygonatum biflorum*. Important summer and fall herbs are *Microstegium vimineum*, *Aster divaricatus*, *A. undulatus*, *A. cordifolius*, *Prenanthes altissima*, *Solidago caesia*, *S. flexicaulis*, *Panicum boscii*, *Verbesina occidentalis*, and *Polygonum scandens*. Ferns are *Polystichum acrostichoides*, *Dryopteris marginalis*, *Thelypteris noveboracensis*, and *T. hexagonoptera*.

Vegetation and Plant Succession

A mixed mesophytic forest is developing on HFR through a mosaic of primary and secondary succession. Seed rain from the conterminous unmined area and the intermixed remnant seed bank have enabled plant colonization and succession to occur throughout the three major topographic positions: highwall, bench, and outslope. Vegetation is characteristic of mid-successional stages and invading or volunteering woody and herbaceous species are mostly native. The original plantings of *Robinia pseudoacacia* and seeded exotic *Festuca elatior* and *Lespedeza cuneata* are actively being replaced. Invading tree species, at present, are dominated by those with easily dispersed propagules carried by wind, e.g., *Acer rubrum* and *Liriodendron tulipifera*. The seral stages of progressive succession at HFR are similar in development to the four other pre-SMCRA surface-mined areas that have been studied (Thompson et al. 1984; Thompson et al. 1986; Thompson and Wade 1991; Thompson et al. 1996; Wade and Thompson 1999).

ANNOTATED LIST OF VASCULAR PLANTS

The annotated plant list is arranged alphabetically by family and species. An asterisk (*) precedes an exotic taxon. Scientific names are followed by habitats, relative abundance, and collector's number.

Habitats created by surface coal mining are designated with a numbered code: 1 = highwall, 2 = bench, 3 = outslope, and 4 = wetland areas. Relative abundance categories (frequency of occurrence) are modified from Thompson and Jones (2001): Abundant (A)—dominant or codominant (thousands of individuals or colonies); Frequent (F)—easily or generally encountered but not dominant (hun-

dreds of individuals or colonies); Occasional (O)—widely scattered but not difficult to locate (31 to 100 individuals or colonies); Infrequent (I)—found in several locations but difficult to locate (6 to 30 individuals or colonies); and Rare (R)—difficult to find and limited to one or two localities (1 to 5 individuals or colonies). Relative abundance for each HFR taxon was determined through field observations of each species and refers to the overall distribution among all habitats.

Herbarium voucher specimens are those of Barbara L. Rafaill (R), Ralph L. Thompson (T), and Thompson and Rafaill (T & R).

EQUISETOPHYTA

Equisetaceae
Equisetum arvense L. 4; F. *T 01-20*

LYCOPODIOPHYTA

Lycopodiaceae
Lycopodium digitatum Dill. ex A. Braun 2; R. *T 01-681*

POLYPODIOPHYTA

Aspleniaceae
Asplenium platyneuron (L.) Oakes 1, 2; I. *T 87-820*
Athyrium thelypteroides (Michx.) Desv. 1; I. *T 96-442*
Dryopteris marginalis (L.) A. Gray 3; I. *T & R 88-472*
Polystichum acrostichoides (Michx.) Schott 2, 3; O. *T 87-834*
Thelypteris hexagonoptera (Michx.) Weath. 3; I. *T & R 88-2429*
T. noveboracensis (L.) Nieuwl. 3; O. *T & R 88-467*
Blechnaceae
Woodwardia areolata (L.) Moore 4; R. *T 89-1347*
Dennstaedtiaceae
Pteridium aquilinum (L.) Kuhn. 1; I. *T & R 88-433*
Ophioglossaceae
Botrychium dissectum Spreng. 2; R. *T 89-500*
B. virginianum (L.) Sw. 3; I. *T & R 88-463*

PINOPHYTA

Cupressaceae
Juniperus virginiana L. 2; R. *T & R 93-173*
Pinaceae
Pinus virginiana P. Mill. 1; R. *T & R 88-459*

MAGNOLIOPHYTA—MAGNOLIOPSIDA

Aceraceae
Acer rubrum L. 1, 2, 3; F. *R 596*
A. saccharum Marsh. 1, 2, 3; O. *T & R 88-445*
Anacardiaceae
Rhus copallinum L. 1, 2; O. *T & R 93-169*
R. glabra L. 1, 3; I. *R 591*
Toxicodendron radicans (L.) Kuntze 1, 2, 3; F. *T 89-1646*
Apiaceae
Cicuta maculata L. 4; I. *T 96-434*
Cryptotaenia canadensis (L.) DC. 1, 2, 3; I. *R 896*
**Daucus carota* L. 1, 2; I. *R 919*
Osmorhiza claytonii (Michx.) C.B. Clarke 3; O. *T & R 88-475*
Sanicula canadensis L. 1, 2; O. *R 878*
S. gregaria E. Bickn. 1; I. *T & R 93-178*
S. trifoliata E. Bickn. 1; R. *T & R 93-179*
Thaspium barbinode (Michx.) Nutt. 2, 3; I. *T & R 93-160*
Apocynaceae
Apocynum cannabinum L. 2, 4; O. *R 903*
Araliaceae
Aralia racemosa L. 1; R. *T 88-2162*
Aristolochiaceae
Asarum canadense L. 2; I. *T 01-27*
Asclepiadaceae
Asclepias exaltata L. 1; R. *T & R 93-176*
A. syriaca L. 4; R. *T 96-437*
Asteraceae
**Achillea millefolium* L. 1, 2; O. *T 87-829*
Ambrosia artemisiifolia L. 1, 2; O. *T 88-2136*
A. trifida L. 2. 4; F. *R 541*
**Arctium minus* Schk. 2; R. *R 972*
Aster cordifolius L. 1, 2, 3; F. *T 88-2721*
A. divaricatus L. 1, 2, 3; F. *T & R 88-2454*
A. dumosus L. 1, 2; I. *T & R 88-2448*
A. lateriflorus (L.) Britt. 1, 3; O. *T 88-2716*
A. paternus Cronq. 1, 2; I. *R 971*
A. phlogifolius (Muhl.) Nees 1; R. *T 88-2706*
A. pilosus Willd. 2; O. *T 88-2735*
A. undulatus L. 1, 3; O. *T 88-2715*
Bidens comosa (A. Gray) Wieg. 4; I. *T 96-436*
B. frondosa L. 4; F. *T & R 88-2414*
B. polylepis S.F. Blake 4; O. *T & R 88-2472*

Cacalia atriplicifolia L. 2, 3; I. *R 952*
**Chrysanthemum leucanthemum* L. 1, 2; O. *T 87-830*
Conyza canadensis (L.) Cronq. 2; R. *T & R 88-2438*
Coreopsis major Walt. 1; O. *R 909*
Erechtites hieracifolia (L.) Raf. 2; I. *R 739*
Erigeron annuus (L.) Pers. 2; I. *R 886*
E. philadelphicus L. 2; O. *T & R 89-503*
Eupatorium fistulosum Barratt 1, 4; O. *T & R 88-2424*
E. rotundifolium L. 2; I. *T 88-2164*
E. rugosum Houtt. 1, 2, 3; F. *T 88-2736*
E. serotinum Michx. 4; O. *T & R 88-2406*
E. sessilifolium L. 2; R. *T 88-2187*
Gnaphalium obtusifolium L. 1; I. *T & R 88-2411*
Helianthus decapetalus L. 2; O. *R 953*
H. microcephalus Torr. & Gray 1, 2; O. *T & R 88-2437*
H. tuberosus L. 1; R. *T 96-439*
Hieracium gronovii L. 2; I. *T & R 88-2432*
H. paniculatum L. 1; I. *T 88-2161*
H. venosum L. 1, 2; O. *T & R 88-443*
Lactuca canadensis L. 3; I. *T 88-2120*
L. floridana (L.) Gaertn. 2, 3; O. *T 88-2193*
**L. serriola* L. 2; R. *T 88-2186*
Prenanthes altissima L. 2, 3; O. *T 88-2738*
Rudbeckia fulgida Ait. 2; I. *T 88-2116*
R. hirta L. 2; R. *T 96-435*
Senecio anonymus Wood 1; O. *R 873*
Silphium trifoliatum L. 1, 2; I. *T 88-2110*
Solidago arguta Ait. 1, 2; F. *T & R 88-2459*
S. bicolor L. 1, 2; I. *T & R 88-2453*
S. caesia L. 1, 3; F. *R 594*
S. erecta Pursh 1, 2; O. *T & R 88-2733*
S. flexicaulis L. 3; F. *T & R 88-2413*
S. gigantea Ait. 3, 4; F. *T 88-2103*
S. nemoralis Ait. 1, 2; F. *T & R 88-2420*
S. rugosa P. Mill. 2; O. *T & R 88-2421*
**Sonchus asper* (L.) Hill 1; R. *R 894*
**Taraxacum officinale* Weber 2; I. *T & R 86-14*
**Tussilago farfara* L. 1, 4; I. *T & R 93-166*
Verbesina occidentalis (L.) Walt. 1; I. *T & R 88-2401*
Vernonia gigantea (Walt.) Trel. 4; O. *T 88-2141*

Balsaminaceae
Impatiens capensis Meerb. 4; A. *R 536*
I. pallida Nutt. 1, 4; A. *T 88-2197*

Berberidaceae
Caulophyllum thalictroides (L.) Michx. 3; O. *T & R 89-523*
Podophyllum peltatum L. 1, 3; O. *T & R 86-516*

Bignoniaceae
**Paulownia tomentosa* (Thunb.) Steud. 1; R. *T & R 93-157*

Brassicaceae
Arabis laevigata (Muhl.) Poir. 3; I. *T 01-31*
**Barbarea vulgaris* R. Br. 2; O. *T 01-45*
Cardamine concatenata (Michx.) O. Swartz. 2, 3; F. *T 01-40*
**C. hirsuta* L. 2; O. *T & R 86-15*

Caesalpiniaceae
Cercis canadensis L. 1, 2; I. *T & R 86-20*
Chamaecrista nictitans (L.) Moench 1, 2; O. *T 88-2112*

Campanulaceae
Campanula americana L. 2; I. *T 96-431*
C. divaricata Michx. 1; I. *T 88-2150*
Lobelia inflata L. 2; O. *T 88-2181*
L. siphilitica L. 4; I. *T 88-2137*

Caprifoliaceae
Sambucus canadensis L. 1, 2, 4; F. *T 89-1642*
Triosteum perfoliatum L. 1; R. *T & R 88-451*

Caryophyllaceae
**Cerastium vulgatum* L. 2; I. *T & R 93-177*
Paronychia canadensis (L.) Wood 3; R. *R 882*
Stellaria pubera Michx. 2; O. *T 01-30*

Chenopodiaceae
**Chenopodium album* L. 2; R. *T & R 88-2436*

Clusiaceae
Hypericum mutilum L. 4; O. *R 963*
H. punctatum Lam. 2; I. *R 929*

Convolvulaceae
Ipomoea pandurata (L.) G.F.W. Meyer 2, 3; O. *T 88-2198*

Cornaceae
Cornus florida L. 2, 3; O. *T 01-38*
Nyssa sylvatica Marsh. 1, 2, 3; F. *T 89-1643*

Crassulaceae
Sedum ternatum Michx. 1, 3; F. *T & R 89-510*

Cuscutaceae
Cuscuta pentagona Engelm. 4; O. *T 96-441*

Ericaceae
Oxydendrum arboreum (L.) DC. 1, 2, 3; F. *T & R 88-2464*

Rhododendron cumberlandense E.L. Braun 1; R. *T & R 93-156*
Vaccinium corymbosum L. 1, 3; O. *R 639*
Euphorbiaceae
Acalypha rhomboidea Raf. 2; I. *T 88-2188*
Euphorbia corollata L. 1; R. *T 88-2111*
E. maculata L. 2; R. *T 88-2749*
Fabaceae
Amphicarpaea bracteata (L.) Fern. 3, 4; F. *T & R 88-2400*
**Coronilla varia* L. 2; R. *T & R 93-164*
Desmodium glabellum (Michx.) DC. 1, 2; O. *T & R 88-2426*
D. nudiflorum (L.) DC. 3; I. *T 88-2104*
D. paniculatum (L.) DC. 2; O. *T & R 88-2431*
**Lespedeza cuneata* (Dum. Cours) G. Don 1, 2; I. *T & R 88-2402*
L. intermedia (S. Wats.) Britt. 1, 2; F. *T & R 88-2422*
**L. stipulacea* Maxim. 2; O. *T 88-2106*
**L. striata* (Thunb.) Hook. & Arnott 2; O. *T 88-2203*
**Medicago lupulina* L. 2; R. *T & R 93-163*
**Melilotus albus* Medic. 2; R. *T 89-1346*
Robinia pseudoacacia L. 2, 3; F. *T & R 88-439*
**Trifolium hybridum* L. 2; R. *T & R 93-171*
**T. pratense* L. 2; I. *R 918*
Vicia caroliniana Walt. 1, 2; I. *T 01-32*
Fagaceae
Quercus prinus L. 3; O. *T 88-2205*
Q. rubra L. 1, 2, 3; O. *T & R 93-158*
Q. velutina Lam. 2, 3; I. *T 96-427*
Fumariaceae
Dicentra cucullaria (L.) Bernh. 1, 3; O. *T 01-44*
Gentianaceae
Gentiana decora Pollard 4; R. *T 88-2708*
Geraniaceae
Geranium maculatum L. 2, 3; O. *T 01-41*
Hippocastanaceae
Aesculus flava Ait. 2, 3; O. *R 897*
Hydrangeaceae
Hydrangea arborescens L. 1, 2; F. *R 901*
Hydrophyllaceae
Hydrophyllum virginianum L. 3; F. *T & R 89-511*
Juglandaceae
Carya glabra (P. Mill.) Sweet 2; R. *T 89-1632*
Juglans nigra L. 1; R. *T & R 88-2452*
Lamiaceae
Collinsonia canadensis L. 2, 3; I. *T & R 88-2405*
Lycopus virginicus L. 4; O. *T & R 88-2428*
Monarda clinopodia L. 2; I. *R 936*
**Prunella vulgaris* L. 1, 2; O. *T 88-2175*
Pycnanthemum pycnanthemoides (Leavenw.) Fern. 1, 2; I. *R 544*
Salvia lyrata L. 2,4; I. *T & R 93-165*
Scutellaria elliptica Muhl. 1, 2; I. *R 890*
S. ovata Hill 3; R. *R 965*
Stachys nuttallii Shuttlw. ex Benth. 1, 3; O. *R 877*
Lauraceae
Sassafras albidum (Nutt.) Nees 1, 3; I. *R 908*
Linaceae
Linum striatum Walt. 4; I. *R 917*
L. virginianum L. 4; R. *T 96-433*
Magnoliaceae
Liriodendron tulipifera L. 1, 2, 3; F. *R 875*
Magnolia acuminata L. 2; R. *R 898*
Oleaceae
Fraxinus americana L. 1, 2, 3; O. *T & R 88-460*
Onagraceae
Circaea lutetiana L. var. *canadensis* L. 3; O. *T 87-833*
Epilobium coloratum Biehler 4; O. *T & R 88-2404*
Ludwigia alternifolia L. 4; O. *T 88-2119*
Oenothera biennis L. 1; I. *T 88-2185*
Oxalidaceae
Oxalis grandis Small 1; O. *R 893*
O. stricta L. 2; I. *T 88-2192*
O. violacea L. 3; I. *T & R 89-517*
Papaveraceae
Sanguinaria canadensis L. 1, 3; O. *T 01-37*
Phytolaccaceae
Phytolacca americana L. 1, 3; O. *R 944*
Plantaginaceae
**Plantago lanceolata* L. 2; I. *R 906*
P. rugelii Decne. 2; O. *T 88-2127*
Platanaceae
Platanus occidentalis L. 3; I. *R 593*
Polemoniaceae
Phlox amplifolia Britt. 2; I. *R 738*
Polygalaceae
Polygala senega L. 2; I. *T 87-822*
Polygonaceae
**Polygonum cespitosum* Blume var. *longisetum* (DeBruyn) Stewart 4; O. *T & R 88-2444*
P. punctatum Ell. 4; F. *T & R 88-2408*

P. sagittatum L. 4; F. *T & R 88-2425*
P. scandens L. 2, 3; F. *R 964*
P. virginianum L. 2; R. *T 89-1634*
**Rumex acetosella* L. 1, 2; F. *R 957*
**R. crispus* L. 4; I. *R 885*
**R. obtusifolius* L. 4; O. *R 871*
Portulacaceae
Claytonia caroliniana Michx. 2; I. *T 01-34*
Primulaceae
Lysimachia quadrifolia L. 1; O. *R 874*
L. tonsa (Wood) Kunth 1; I. *R 923*
Pyrolaceae
Chimaphila maculata (L.) Pursh 1; I. *T 87-821*
Ranunculaceae
Anemone quinquefolia L. 3; I. *T & R 86-05*
A. virginiana L. 2; O. *R 914*
Anemonella thalictroides (L.) Spach. 3; F. *T 01-28*
Cimicifuga racemosa (L.) Nutt. 1; R. *T 96-438*
Clematis virginiana L. 1, 3, 4; F. *R 549*
Delphinium tricorne Michx. 3; O. *T 01-36*
Ranunculus abortivus L. 2; O. *T & R 86-13*
R. hispidus Michx. 2, 4; O. *T 01-23*
R. recurvatus Poir. 3; I. *T & R 86-40*
Thalictrum dioicum L. 2, 3; O. *T 01-42*
Rosaceae
Agrimonia parviflora Ait. 4; O. *T 89-1635*
A. rostellata Wallr. 2; R. *T 88-2170*
Aruncus dioicus (Walt.) Fern. 1; R. *R 899*
Fragaria virginiana Duchesne 2; I. *R 946*
Geum canadense Jacq. 2, 3; O. *R 928*
Porteranthus trifoliatus (L.) Britt. 3; R. *T & R 93-155*
Potentilla canadensis L. 1, 2; F. *T &R 86-07*
P. simplex Michx. 1, 2; O. *T & R 86-34*
Prunus serotina Ehrh. 2, 3; I. *T & R 88-456*
**Rosa multiflora* Thunb. 2; I. *T &R 88-431*
Rubus allegheniensis Porter 1, 2, 3; F. *T & R 93-174*
R. flagellaris Willd. 2; O. *T & R 86-25*
R. occidentalis L. 2, 3; O. *T & R 88-468*
Rubiaceae
Galium aparine L. 2, 3; F. *T & R 86-35*
G. lanceolatum Torr. 1; I. *T & R 93-159*
G. latifolium Michx. 3; I. *T 88-2114*
G. tinctorium L. 4; O. *R 967*
G. triflorum Michx. 3; F. *T 88-2113*
Hedyotis purpurea (L.) Torr. & Gray 2; I. *R 888*
Salicaceae
Salix nigra Marsh. 4; O. *T & R 88-448*
S. sericea Marsh. 4; O. *T & R 88-474*
Saxifragaceae
Heuchera americana L. 1, 3; I. *T & R 88-434*
Scrophulariaceae
Chelone glabra L. 4; R. *T 88-2702*
Mimulus ringens L. 4; O. *R 933*
Pedicularis canadensis L. 2; I. *T & R 86-33*
**Veronica arvensis* L. 2; O. *T & R 88-440*
**V. officinalis* L. 2; R. *T & R 88-458*
Solanaceae
Physalis heterophylla Nees 2; R. *T & R 93-167*
Tiliaceae
Tilia americana L. 2, 3; I. *T & R 88-457*
Ulmaceae
Ulmus rubra Muhl. 2; R. *R 895*
Urticaceae
Laportea canadensis (L.) Wedd. 2, 3; F. *R 941*
Pilea pumila (L.) A. Gray 1, 4; O. *T 96-440*
Verbenaceae
Verbena urticifolia L. 4; I. *R 973*
Violaceae
Viola canadensis L. 1, 3; F. *T 01-33*
V. palmata L. 3; F. *T 01-39*
V. pubescens Ait. 3; O. *T 01-25*
V. sororia Willd. 1,2, 3; F. *T & R 89-522*
Vitaceae
Parthenocissus quinquefolia (L.) Planch. 3; O. *R 595*
Vitis aestivalis Michx. 2, 3; F. *R 550*

MAGNOLIOPHYTA—LILIOPSIDA

Araceae
Arisaema triphyllum (L.) Schott 3; R. *T & R 86-39*
Commelinaceae
**Commelina communis* L. 2; I. *T 88-2132*
Tradescantia subaspera Ker-Gawl. 2; I. *R 869*
Cyperaceae
Carex amphibola Steud. 3; O. *T & R 88-430*
C. debilis Michx. 4; O. *T & R 88-461*
C. frankii Kunth 4; R. *T 87-846*
C. laxiflora Lam. 3; O. *T 96-432*
C. lurida Wahl. 4; O. *T 87-824*
C. prasina Wahl. 4; F. *T 01-21*
C. purpurifera Mack. 1, 3; I. *T & R 88-455*
C. swanii (Fern.) Mack. 3; R. *T & R 93-161*
C. tribuloides Wahl. 4; I. *T 87-826*
C. vulpinoidea Michx. 4; O. *R 872*

Cyperus strigosus L. 4; I. *T 88-2154*
Eleocharis acicularis (L.) Roemer & Schultes 4; F. *T & R 86-45*
E. ovata (Roth) Roemer & Schultes 4; O. *T 88-2178*
Rhynchospora capitellata (Michx.) Vahl 4; O. *T 88-2184*
Scirpus cyperinus (L.) Kunth 4; O. *T 88-2711*
S. polyphyllus Vahl 4; O. *T 96-428*

Dioscoreaceae
Dioscorea quaternata (Walt.) J. F. Gmel. 1, 3; O. *T 88-2725*

Iridaceae
Sisyrinchium angustifolium P. Mill. 2; I. *T & R 88-423*

Juncaceae
Juncus acuminatus Michx. 4; O. *T 88-2183*
J. effusus L. var. *solutus* Fern. & Wieg. 4; O. *R 870*
J. tenuis Willd. 2; O. *T 88-2126*

Liliaceae
**Allium vineale* L. 2; R. *T & R 88-471*
Disporum lanuginosum (Michx.) Nichols. 1, 3; I. *T & R 89-519*
Erythronium americanum Ker-Gawl. 2; O. *T 01-22*
Polygonatum biflorum (Walt.) Ell. 1, 3; F. *T 01-24*
Smilacina racemosa (L.) Desf. 1, 3; O. *T 87-832*
Trillium erectum L. 3; O. *T 01-29*
T. grandiflorum (Michx.) Salisb. 3; O. *T 01-35*
Uvularia grandiflora J.E. Smith 1, 3; O. *T 01-26*

Orchidaceae
Aplectrum hyemale (Muhl.) Torr. 2; R. *T & R 86-17*
Habenaria clavellata (Michx.) Spreng. 4; R. *T 96-428*
Spiranthes cernua (L.) Rich. 4; R. *T 88-2742*

Poaceae
**Agrostis gigantea* Roth 4; O. *T & R 88-454*
A. perennans (Walt.) Tuckerm. 1, 2; F. *T & R 88-2460*
Andropogon virginicus L. 1, 2; F. *T 88-2701*
Aristida dichotoma Michx. 1, 2; F. *T 88-2741*
Bromus pubescens Muhl. 3; O. *T & R 93-175*
**Dactylis glomerata* L. 2; O. *T 96-427*
Danthonia compressa Aust. 1, 2; A. *T & R 93-168*
**Digitaria ischaemum* (Schreb.) Muhl. 2; I. *T 88-2182*
**Echinochloa crusgalli* (L.) Beauv. 4; O. *T 88-2138*
Elymus hystrix L. 1, 3; O. *T & R 93-181*
E. virginicus L. 1, 2, 3; O. *T 88-2704*
**Festuca elatior* L. 1, 2; F. *R 915*
F. subverticillata (Pers.) Alexeev. 3; O. *T & R 93-162*
Glyceria striata (Lam.) Hitchc. 4; F. *T & R 88-420*
**Holcus lanatus* L. 4; R. *T & R 93-154*
Leersia oryzoides (L.) Swartz 4; F. *T & R 88-2407*
L. virginica Willd. 4; F. *T 88-2131*
**Microstegium vimineum* (Trin.) A. Camus 1, 2, 3, 4; A. *R 537*
Muhlenbergia frondosa (Poir.) Fern. 4; F. *T & R 2410*
M. schreberi J.F. Gmel. 2; I. *T & R 88-2435*
M. sylvatica (Torr.) Torr. 4; R. *T 88-2730*
M. tenuiflora (Willd.) BSP. 1, 3; O. *T & R 88-2412*
Panicum boscii Poir. 1, 2, 3; F. *T & R 88-435*
P. capillare L. 2; I. *T & R 88-2441*
P. clandestinum L. 2, 4; F. *R 883*
P. commutatum Schultes 1, 2; F. *R 887*
P. dichotomiflorum Michx. 4; R. *T & R 88-2455*
P. dichotomum L. 1, 2; F. *R 904*
P. polyanthes Schultes 3; O. *R 925*
P. rigidulum Nees 4; O. *T 88-2163*
Paspalum laeve Michx. 2; I. *T & R 88-2403*
Poa alsodes A. Gray 2; I. *T 88-464*
**P. compressa* L. 2; O. *T & R 93-170*
P. cuspidata Nutt. 3; O. *T & R 89-505*
**P. pratensis* L. 1, 2; O. *T & R 88-422*
Sphenopholis obtusata (Michx.) Scribn. var. *major*
(Torr.) K.S. Erdman 2, 3; O. *T & R 88-464*

Smilacaceae
Smilax ecirrhata (Englem.) Wats. 3; R. *T 88-2703*
S. glauca Walt. 1, 2; F. *T & R 88-469*
S. rotundifolia L. 1, 2, 3; F. *T 88-2191*

Typhaceae
Typha latifolia L. 4; F. *T 88-2128*

CONCLUSIONS

Pre-SMCRA mining techniques on the Henderson Fork Road Surface-mined Area

created unique xeric, mesic, and hydric habitats that have contributed to high species richness and even served as a refugium for the presence of rare species. Flora and vegetation are progressing toward a young mixed mesophytic forest as a result of invading native species from the seed rain and seed bank in conjunction with the favorable habitats resulting from contour surface mining. HFR is well vegetated with plant associations that have developed through mid-successional seral stages of primary and secondary succession. The origin of most of the species are native and the exotics are being replaced as seral stages progress. HFR has a high Sørensen's Index of Similarity with a larger nearby prelaw coal mine. Species richness at HFR is comparable to that found on unmined areas of the same size in the Mixed Mesophytic Forest Region.

In summary, Henderson Fork Road Surface-mined Area is yet another representative of a reclaimed pre-SMCRA coal surface mine that now supports a rich flora and has developed several native plant associations through the process of natural plant succession. This study provides further evidence that pre-SMCRA surface mines do not necessarily result in barren waste areas incapable of supporting post-mining vegetation.

LITERATURE CITED

Braun, E. L. 1950. Deciduous forests of eastern North America. Hafner Press, New York, NY.

Browne, Jr., E. T. and R. Athey. 1992. Vascular plants of Kentucky: an annotated checklist. The University Press of Kentucky, Lexington, KY.

Childress, J. D. 1992. Soil survey of Bell and Harlan Counties, Kentucky. U.S. Department of Agriculture, Soil Conservation Service, Washington, DC.

Fenneman, N. M. 1938. Physiography of eastern United States. McGraw-Hill, New York, NY.

Gleason, H. A., and A. Cronquist. 1991. Manual of vascular plants of northeastern United States and adjacent Canada, 2nd ed. New York Botanical Garden, Bronx, NY.

[KSNPC] Kentucky State Nature Preserves Commission. 2000. Rare and extirpated biota of Kentucky. J. Ky. Acad. Sci. 61:115–132.

Küchler, A. W. 1964. Potential natural vegetation of the conterminous United States. (Map and accompanying manual). American Geographical Society, Special Publication Number 36, New York, NY.

Mueller-Dombois, D., and H. Ellenberg. 1974. Aims and methods of vegetation ecology. John Wiley and Sons, New York, NY.

Rafaill, B. L. 1988. Soil characteristics and vegetational features of abandoned and artifically revegetated surface mines in the Cumberland Mountains. Ph.D. Dissertation. Southern Illinois University, Carbondale, IL.

Rice, C. L., and E. K. Maughan. 1978. Geologic map of the Kayjay Quadrangle and part of the Fork Ridge Quadrangle, GQ 1505, Bell and Knox Counties, Kentucky. U.S. Geological Survey, Reston, VA.

Strausbaugh, P. D., and E. L. Core. 1978. Flora of West Virginia, second edition. Seneca Books, Grantsville, WV.

Thompson, R. L., and R. L. Jones. 2001. Woody plants of Rock Creek Research Natural Area and watershed uplands, Laurel County, Kentucky. Castanea 66:275–287.

Thompson, R. L., and J. R. MacGregor. 1986. *Liparis loeselii* (Orchidaceae) documented in Kentucky. Trans. Ky. Acad. Sci 47:138–139.

Thompson, R. L., W. G. Vogel, and D. D. Taylor. 1984. Vegetation and flora of a coal surface-mined area in Laurel County, Kentucky. Castanea 49:111–126.

Thompson, R. L., W. G. Vogel, G. L. Wade, and B. L. Rafaill. 1986. Development of natural and planted vegetation on surface mines in southeastern Kentucky. Pages 145–153 in J. Harper and B. Plass (eds), Proceedings, 3rd Annual Meeting American Society for Surface Mining and Reclamation, March 17–20, 1986, Jackson, MS.

Thompson, R. L., and G. L. Wade. 1991. Flora and vegetation of a 12-year-old coal surface-mined area in Rockcastle County, Kentucky. Castanea 56:99–116.

Thompson, R. L., G. L. Wade, and R. A. Straw. 1996. Natural and planted flora of the Log Mountain Surface-mined Demonstration Area, Bell County, Kentucky. Pages 484–503 in W. L. Daniels, J. A. Burger, and C. E. Zipper (eds), Proceedings, 10th Annual Meeting American Society for Surface Mining and Reclamation, May 18–22, 1996, Knoxville, TN.

Trewartha, G. T. 1968. An introduction to climate, 4th edition. McGraw-Hill, New York, NY.

University of Kentucky Agricultural Weather Center. 1995. Interactive map for Kentucky climate data, 1960–1990. <http:www.ca.uky.edu/agcollege/agweather/analysis2/middlesboro.htm./>

Vogel, W. G. 1981. A guide for revegetating coal minesoils in the eastern United States. U.S. Department of Agriculture Forest Service, General Technical Report NE-68. Broomall, PA.

Wade, G. L., and R. L. Thompson. 1991. The species-area curve and regional floras. Trans. Ky. Acad. Sci. 52:21–26.

Wade, G. L., and R. L. Thompson. 1993. Species richness on five partially reclaimed Kentucky surface mines. Pages 307–314 in B. A. Zamora, and R. E. Connolly (eds), Proceedings, 13th Annual Meeting, American Society for Surface Mining and Reclamation, May 16–19, 1993, Spokane, WA.

Wade, G. L., and R. L. Thompson. 1999. Woody vegetation and succession on the Fonde Surface Mine Demonstration Area, Bell County, Kentucky. Pages 339–351 in S. A. Bengdon, and D. M. Bland (eds), Proceedings, 16th Annual Meeting of American Society for Surface Mining and Reclamation, August 13–19, 1999, Scottsdale, AZ.

J. Ky. Acad. Sci. 63(1):65. 2002.

NOTE

Corrections and Additions to: Campbell, J.J.N. 2000. Notes on North American *Elymus* species (Poaceae) with paired spikelets. I. *E. macgregorii* sp. nov. and *E. glaucus* ssp. *mackenzii* comb. nov. J. Ky. Acad. Sci. 61:88–98.—(1) The date of "Dewey (1892)" should be 1894. (2) After correspondence and exchange of material with A. Haines (Freeport, ME), Campbell's notes on the status of *Elymus macgregorii* R. Brooks & J.J.N. Campbell near the edge of its distribution in Maine can be clarified. Although this species does appear to remain distinct there, it is uncomfortably similar to sympatric *E. virginicus* var. *jejunus*. Its spike rachis internode lengths and spikelet dimensions, including awn lengths, tend to be near the low end of the ranges reported in Campbell (2000). Its auricles tend to be light brown, rather than purplish black. Also, as expected further north, the anthesis of *E. macgregorii* is delayed, generally to July. However, *E. virginicus* var. *jejunus* may still be distinguished by its later flowering, albeit by only about 10 days, and by its glabrous foliage and spikes, in addition to any minor differences in spike dimensions. (3) County records (with herbarium acronyms in parentheses) for *E. macgregorii* can be appended as follows. Some of these counties were previously recorded based largely on old collections, but confirmation from additional collections is important given the new status of the species. CONNECTICUT, New Haven (NEBC*) and Windham (NEBC); IOWA, Story (ISC); MAINE, Cumberland (MAINE*, NEBC), Oxford (MAINE, NEBC), Penobscot (GH, MAINE, NEBC), Somerset (MAINE*, NEBC), and York (GH, NEBC); MASSACHUSETTS, Essex (NEBC), Middlesex (NEBC), and Worcester (NEBC); NEW HAMPSHIRE, Coos (NEBC*) and Grafton (NEBC); RHODE ISLAND, Providence (NEBC); and VERMONT, Essex (NEBC). Although some material may be transitional to *E. virginicus*, especially the asterisked records, we are generally confident of the overall distribution of this species in New England.—**Arthur Haines,** New England Wildflower Society, 180 Hemenway Road, Framingham, Massachusetts 01701; **Julian J.N. Campbell,** The Nature Conservancy (Kentucky Chapter), 642 West Main Street, Lexington, Kentucky 40508.

J. Ky. Acad. Sci. 63(1):66–73. 2002.

Some Abstracts from the 87th Meeting of the Kentucky Academy of Science

Edited by Robert J. Barney

AGRICULTURAL SCIENCES

Persistence and performance of esfenvalerate residues on spring and fall broccoli. GEORGE F. ANTONIOUS, Land-Grant Program, Kentucky State University, Frankfort, KY 40601.

The efficacy of esfenvalerate (Asana XL, 8.4% EC) at 7.0 g (AI)/ha on the feeding damage to broccoli was tested against the flea beetle (FB), *Phyllotreta cruciferae* Goeze (Chrysomelidae: Coleoptera) and the imported cabbage worm (ICW), *Pieris rapae* L. (Pieridae: Lepidoptera) under field conditions. Esfenvalerate residues on spring broccoli were 12.2, 5.2, and 2.9 μg/cm^2 on the leaves and 0.13, 0.05, and 0.02 ppm on the heads at 1 hour, 1 day, and 3 days, respectively. On the basis of half-life ($T_{1/2}$) values, persistence of esfenvalerate on spring broccoli leaves ($T_{1/2}$ = 1 day) was shorter than on fall broccoli ($T_{1/2}$ = 1.6 days). $T_{1/2}$ values were 2.1 and 3.6 days on spring and fall broccoli heads, respectively. The large surface area of broccoli heads allows much more esfenvalerate residues to be retained on their surface. Only trace levels (0.001 ppm) were detected in/on the heads 14 days following spraying. Periodic sweep-net collections and examination of the leaves in treated and untreated broccoli plots revealed mean FB reductions of nearly 98% one-week post application compared to untreated plots. The residual toxicity of esfenvalerate was also effective for 2 weeks in reducing population density of ICW by 69% on broccoli leaves. The impact of esfenvalerate on feeding damage to broccoli leaves was established by counting the number of feeding holes made by FB on spring broccoli and ICW on fall broccoli. Leaf area ingested increased with a linear relationship between the number of holes and number of insects. Results indicated that forage destruction by FB and ICW was significantly reduced by esfenvalerate application.

Interaction of soil organic matter with pyrethrins and piperonyl butoxide. GAYATRI A. PATEL, GEORGE F. ANTONIOUS, Land-Grant Program, Kentucky State University, Frankfort, KY 40601; and JOHN C. SNYDER and MARK S. COYNE, Department of Horticulture and Department of Agronomy, University of Kentucky, Lexington, KY 40506.

Soil organic matter plays a significant role in binding organic pollutants like pesticides and thus affects pesticide movement in soil, runoff water, and groundwater. Soil management practices for growing vegetable crops on highly erodible land (10% slope) have been evaluated by the Water Quality Program at Kentucky State University. Studies were conducted to determine the influence of landscape features and soil amendments on pesticide movement into runoff and infiltration water. Interaction of soil organic matter with pyrethrins (Pys), the major insecticidal components obtained from the pyrethrum daisy (*Tanacetum cinerariifolium*) and piperonyl butoxide (PBO, a pyrethrum synergist) was studied. Two soil management practices were used in this study, soil mixed with yard waste compost (COM) at 50 tons/acre on dry weight basis and no-mulch (NM) soil. Adsorption isotherm experiments were carried out using known concentrations of Pys and PBO prepared in water with known amounts of COM soil or NM soil at constant temperature and pressure for a period of time such that an equilibrium was attained. Pys and PBO extracts were purified and concentrated using solid-phase extraction cartridges containing C_{18}-octadecyl bonded silica. Residues of Pys and PBO were quantified using a high-performance liquid chromatograph equipped with a UV detector. The interaction of Pys and PBO with humic acid was studied by reverse-phase thin layer chromatography (TLC). Adsorption studies showed that compost amended soil adsorbed more Pys and PBO compared to native soil (no-mulch soil). Py-I adsorption was higher than Py-II and PBO. Reversed-phase TLC results showed that humic acid, a significant component of organic matter, reduced Pys and PBO mobility on the TLC plates. Pys and PBO mobility decreased as the concentration of humic acid in the mobile phase increased.

Insecticidal performance of methyl ketones from wild tomato accessions. LISA M. HAWKINS, GEORGE F. ANTONIOUS, Land-Grant Program, Kentucky State University, Frankfort, KY 40601; and DOUGLAS L. DAHLMAN, Department of Entomology, University of Kentucky, Lexington, KY 40546.

The potential of using allelochemicals from the leaves of wild tomato accessions for controlling mites and herbivorous insects of vegetables is explored in this study. Crude extracts of three accessions of *Lycopersicon hirsutum f. typicum*; six accessions of *L. hirsutum f. glabratum*; two accessions of *L. pennellii*; and one accession of *L. pimpinellifolium* were tested for their insecticidal efficiency using a 6 hour no-choice bioassay test against the tobacco hornworm (*Manduca sexta*) and tobacco budworm (*Heliothis virescens*). Crude extracts of 5 accessions of *L. hirsutum f. glabratum* (PI 251304, LA 407, PI 134417, PI 134418, and PI 126449) were evaluated using filter paper bioassay test for the length of time mortality occurred. Seven days after the application of 100 μL of crude extract to the filter paper, the ethanol extracts of *L. hirsutum f. glabratum* (PI 134417) continued to have a 53% mortality for tobacco budworm, while the hexane extract continued to exhibit 100% mortality 15 days after application. Twelve days after the application of 100 μL of crude extract to the filter paper, the ethanol extracts of *L. hirsutum f. glabratum* (PI 134418) continued to have 25% mortality against the tobacco hornworm. Four methyl ketones (2-undecanone, 2-dodecanone, 2-tridecanone,

and 2-pentadecanone) of 99% purity were also screened for mortality against the two spotted spider mite (*Tetranychus urticae*) and three herbivorous insects: tobacco hornworm (*Heliothis virescens*), tobacco budworm (*Manduca sexta*), and the green peach aphid (*Myzus persicae*) using a no-choice bioassay. It was determined that 2-tridecanone was the most effective at the lowest dose with LC_{50} of 0.015 μM/cm² of filter paper surface area for tobacco hornworm and budworm, while 2-dodecanone was the most effective at the lowest dose with LC_{50} of 0.06 μM/cm² for the green peach aphid and 0.15 μM/cm² for the two spotted spider mite.

Occurrence of trifluralin residues in soil and runoff water from tomato production. MATTHEW A. PATTERSON and GEORGE F. ANTONIOUS, Land-Grant Program, Kentucky State University, Frankfort, KY 40601.

Intensive use of pesticides in many parts of the United States poses a potential for serious non-point source contamination of soil and receiving water. The use of pesticides in plant protection releases large quantities of pesticides into rivers and streams through runoff water and sediment (following natural rainfall or irrigation) and into groundwater through infiltration (seeping). Monitoring the fate of pesticide residues is needed particularly in Kentucky where most of the arable lands are highly erodible. Loss of pesticides into the environment during and following pesticide spraying cannot be avoided, but can be minimized. Knowledge of how, when, and where pesticide residues reach the edge of the field and streams and how these factors relate to applications is essential in order to reduce the quantity of pesticides reaching surface water and the nation's water resources. A field study was conducted on a Lowell silty loam soil (2% organic matter, pH 6.7) located at Kentucky State University Research Farm, Franklin County, KY. The soil has an average of 12% clay, 75% silt, and 13% sand. Runoff plots (universal soil loss equation (USLE) standard plots) of 22 × 3.7 m (n = 18), on a soil of 10% slope were established. Plots were separated using metal borders 20 cm high above the ground level. Trifluralin (430 g/L EC; Treflan), a selective preemergence soil-herbicide, was used at the rate of 0.75 lb/acre to control broadleaf weeds and annual grasses. Three soil management practices were used 1) tall fescue (*Festuca* sp., Kentucky 31) strips, 30 cm wide planted between tomato (*Lycopersicon esculentum cv.* Fabulous) rows across the contour of the slope at 5 rows of filter strips/plot, 2) soil mixed with yard waste compost at 50 t/acre on dry weight basis, and 3) no-mulch treatment (rototilled bare soil). Following natural rainfall events, runoff (soil-water suspension) was collected and quantified at the lower end of each plot using tipping-bucket runoff metering apparatus. Concentrations of trifluralin residues were higher in compost amended soil than the no-mulch treatment.

Foliar phenolic variation in wild tomato accessions. AKUA HENAKU-LARBI and GEORGE F. ANTONIOUS, Land-Grant Program, Kentucky State University, Frankfort, KY 40601.

There is an increasing interest in the use of natural plant products for insect control. Phenols constitute one of the most widespread group of compounds in higher plants. Phenols in plants have a variety of functions such as protection from herbivores, protection from ultraviolet light, and biocidal effects against bacteria and fungi. A significant positive correlation was found between the concentrations of total phenols in commercial tomato leaves with mortality of the cotton leaf worm, *Spodoptera littoralis* (Boisduvar). Tomato leaf phenols may cause the leaves to be less suitable for insect growth or may influence leaf palatability. Many researchers have reported that resistance of certain host plants may depend partially or completely on their phenolic compounds. Recent reports have been shown to support the concept that the breakdown products of tannins (phenols) behave as toxins and feeding deterrents, particularly for phytophagous insects that do not typically feed on diets rich in tannins. Production of phenols as naturally occurring insecticides from wild tomato accessions is explored in this study. Concentrations of total phenols in the leaves of six wild tomato accessions of *Lycopersicon hirsutum f. glabratum* (Mull); three accessions of *L. hirsutum f. typicum* (Humb & Bonpl.); two accessions of *L. pennellii* Corr; and one commercial tomato *Lycopersicon esculentum* cv. Fabulous were determined per unit leaflet surface area (cm²) and per g fresh leaflets. Concentrations of total phenols were significantly higher ($P < 0.05$) in *L. hirsutum f. glabratum* (PI-251304 and PI-134417) compared to *L. esculentum* and *L. hirsutum f. typicum* accessions tested.

Sustainable soil management practices and soil infiltration by pesticides. MICHAEL MASTERS and GEORGE F. ANTONIOUS, Land-Grant Program, Kentucky State University, Frankfort, KY 40601.

The mobility of any pesticide in soil is one of the principal parameters controlling the extent to which a pesticide may represent a risk for surface and groundwater contamination. The Water Quality Projects at Kentucky State University (KSU) are evaluating best management practices for the growing of vegetable crops on highly erodible land (10% slope). Studies were conducted to determine the influence of landscape features on pesticide movement into runoff and infiltration water. Pesticides infiltration into the vadose zone were monitored using pressure-vacuum lysimeters (n = 27). The impact of the soil mulches on movement of trifluralin (a soil applied herbicide), clomazone (a soil applied herbicide), dacthal (a preemergence non-systemic herbicide), and endosulfan (an insecticide) was measured under field conditions. Results indicated the vertical movement of trifluralin, clomazone, dacthal, and endosulfan through the soil into the vadose zone. Cultivation of turf reduced runoff, but did not reduce leaching, of pesticides into the vadose zone. Utilization of vegetative filter strips in agricultural fields resulted in a reduction of the transport of pesticides (e.g.,

endosulfan by 56%, dacthal by 85%, clomazone by 81%) in runoff water allowing for their infiltration into the vadose zone. Increased water infiltration can result in the undesirable downward movement of pesticides. Mulching has improved infiltration into the vadose zone as indicated by volume of water collected from the vadose zone. Our current objective at KSU is to study the potential of using soil amendments to improve soil quality, detoxify contaminants, and reduce soil infiltration by pesticides.

An overview of the Kentucky State University pawpaw program. KIRK W. POMPER, Land-Grant Program, Kentucky State University, Frankfort, KY 40601-2355.

Kentucky State University (KSU) has had a comprehensive pawpaw [*Asimina triloba* (L.) Dunal] research program since 1990 with the goal of developing pawpaw into a new high-value tree fruit crop. The program was initiated by Brett Callaway in 1990 and was expanded by Desmond Layne from 1993 to 1997. It has been under the direction of Kirk Pomper since 1998. Current extension activities include:1) a web site (http://www.pawpaw.kysu.edu) for the dissemination of pawpaw information; 2) an annual pawpaw field day, and 3) responses to over 350 telephone calls, emails, and letters each year. The objectives of the research program have been aimed at: 1) understanding the fruit ripening process; 2) conducting pawpaw variety trials; 3) optimizing seedling and clonal propagation methods; 4) enhancing pawpaw germplasm through collection and assessment; and 5) developing orchard management recommendations. Research efforts with Douglas Archbold and Robert Geneve of the University of Kentucky have attempted to understand the fruit ripening process and improve propagation methods, respectively. In 1994, KSU was approved as the USDA National Clonal Germplasm Repository, or gene bank, for *Asimina* spp.; therefore, germplasm evaluation, preservation, and dissemination have been a high priority for the program. There are presently over 1700 accessions (trees) from 17 states and over 40 cultivars contained in the repository orchards. Molecular marker methodologies have been used in fingerprinting cultivars and assessing genetic diversity across the pawpaw's native range. Pawpaw seedlings with promising fruit characteristics have been identified in the repository collection and have been propagated for further evaluation as potential cultivars.

ANTHROPOLOGY

Childhood terrorism and patriotism: a story of the IRA. MICHAEL J. SIMONTON, Northern Kentucky University, Highland Heights, KY 41099.

With reference to traditional Irish history and culture, as well as with references to field interviews with key informants, the author has built a model of factors which can lead children to become terrorists. A history of violence in a culture can become self-perpetuating as a means to social change, especially when seen as part of a revitalization movement in a demoralized culture. Folklore and legend also can act as historical precedent to violence, as well as act as a pedagogical device to teach terrorism and other forms of violence to impressionable, inchoate personalities. Personal experiences with other, older children who are role models can lead to performing terroristic activities without the actor being fully aware of the consequences of such behavior. Violence within the context of terroristic behavior can act as a cathartic release from subconscious issues with sexual identity and sexual repression, as well as acting as a validatory process for developing sexual personality in the form of a "rite-de-passage" which allows a psychologically feminized male to reject the female domain and enter adult status as fully male.

CELL & MOLECULAR BIOLOGY

Magnesium deficiency: a global gene expression study. RACHEL DI TRAPANI, TAMARA HAGEN and PATRICK SCHULTHEIS, Department of Biological Sciences, Northern Kentucky University, Highland Heights, KY 41099.

Magnesium is the second most abundant intracellular cation in the human body. It serves as a cofactor in over 300 enzymatic reactions and has a profound influence on many cellular processes including DNA and protein synthesis, intracellular signal transduction, and cell growth and differentiation. Magnesium deficiency is also implicated in many diseases such as atherosclerosis, stroke, and heart disease. However, the mechanisms by which magnesium deficiency leads to various disease states remain obscure. To elucidate these mechanisms, cDNA microarray technology was used to compare gene expression profiles of various control organs (brain, heart, small intestines, liver, and kidney) to their counterparts from magnesium deficient mice. Magnesium deficiency resulted in the differential expression of numerous genes including those involved in lipid metabolism, antioxidation, ion transport, and signal transduction. Data such as these should lead to a better understanding of magnesium's role in health and disease.

Analysis of a genetic variant of the TβR-I gene in renal cell carcinomas. B. COSTELLO, N. SINGER, J. H. CARTER and T. CHEN, Wood Hudson Cancer Research Laboratory, Newport, KY 41071.

Transforming growth factor-β (TGF-β) type I receptor (TβR-I) is a key element in the TGF-β signaling pathway that is commonly involved in human cancer. Resistance to TGF-β-mediated growth inhibition in kidney cancer is well documented. We hypothesize that genetic alterations in the TGF-β signaling pathway might be associated with renal cancer development or predisposition to renal cancer. In the present study, we investigated the possible association of a genetic variant G > A within intron 7 of the TβR-I gene with renal cell carcinomas. Tumor samples were from archived paraffin-embedded tissue. Normal controls were also from archived specimens with emphasis on age-matched groups that were not diagnosed with any cancer. Polymerase chain reaction and single

strand conformation polymorphism were used to identify the different genotype in the TβR-I gene. Among 28 cases of renal cancer analyzed thus far, 13 were heterozygous and 1 was homozygous for this genetic variant (total 50%). In contrast, only 4 of 29 (13%) samples in the healthy control group were genetic variant carriers. These results suggest that this genetic variant could be an important marker associated with renal cancer. Further investigation of the involvement of genetic alterations of TβR-I is warranted.

Identification and analysis of regulation of cathepsin F in the cultured prostate tumor cell lines: DU-145, LNCaP, and PC-3. N. SINGER, K. STOCKMASTER, E. TABELING, A-M. THOMPSON, E. HUGO and J. H. CARTER, Wood Hudson Cancer Research Laboratory, Newport, KY 41071.

Cancer of the prostate (CaP) is the most commonly diagnosed cancer in American men and the second leading cause of cancer deaths in this group. Although initially responsive to surgery, radiation, and/or hormone-based therapies, the cancer often recurs in the treated patient. Recurrences are characterized by hormone independent growth and metastasis to sites distant from the prostate. Cysteine proteases are intimately involved in metabolic processes, such as intracellular protein turnover, necessary for the survival and growth of tumor cells. The activity of cysteine proteases is regulated in part by interaction with intracellular and extracellular low molecular weight polypeptide inhibitors (stefins and cystatins, respectively). Because of the involvement of these proteins in cellular growth it is possible that the cysteine proteases might be suitable candidate targets for chemotherapy. Based on enzyme activity studies on cellular extracts of cultured prostate tumor cells, we believed the major cysteine proteases to be cathepsin B (CB) and cathepsin L (CL). Additional studies to quantify these enzymes using immunological methods (Western blotting) were unable to detect CL. Recently a new cysteine protease, cathepsin F (CF), was reported in the literature. In our enzymatic assays, CF is indistinguishable from CL, however, commercially available antibodies can differentiate the two proteases. After extensive examination with antibodies to CB, CL, and CF, we have determined that there is no evidence for CL expression whereas CB is the major detected cysteine protease and CF is present in all three cell lines.

Synergistic growth inhibition of the cultured prostate tumor cell lines: DU-145, LNCaP, and PC-3 by α-tocopherol succinate and epidermal growth factor receptor kinase inhibitors. K. LINK, E. HUGO and J. H. CARTER, Wood Hudson Cancer Research Laboratory, Newport, KY 41071.

Prostate cancer (CaP) is the most commonly diagnosed cancer and the second leading cause of cancer deaths in American men. Current treatment of the disease includes surgical resection of the prostate, radiotherapy, cryotherapy, hormonal manipulation, and/or orchiectomy. Recurrent cancer after hormonal manipulation is usually hormone-refractory. Dietary components can play a significant role in reducing both the morbidity and the mortality of CaP. One such dietary component is vitamin E (R,R,R-α-tocopherol). The effect of α-tocopherol on the development of CaP has been extensively studied epidemiologically. In one study of over 29,000 men, dietary supplementation with α-tocopherol led to a 40% reduction in the occurrence of CaP. Although α-tocopherol is a potent antioxidant, similarly active antioxidants do not have the same negative effect on CaP. One of the possible mechanisms of vitamin E activity is thought to be inhibition of the epidermal growth factor receptor (EGFR) kinase; we have tested the effect of α-tocopherol succinate in conjunction with several specific inhibitors of this kinase—Tyrphostin 51 and methyl dihydroxycinnamate (MDHC). The inhibitors were tested for their ability to inhibit the growth of cultured prostatic tumor cells in the presence and absence of vitamin E. Growth inhibition was determined by observing the reduction of MTS, a soluble tetrazolium compound. The amount of MTS reduction is directly proportional to the number of viable cells. We have found evidence for synergistic growth inhibition between vitamin E and EGFR kinase inhibitors thus implying that there are separate mechanisms for growth inhibition by vitamin E and EGFR kinase inhibitors.

CHEMISTRY

Separation and quantification of sesquiterpene hydrocarbons in wild tomato accessions. GEORGE F. ANTONIOUS, Land-Grant Program, and TEJINDER S. KOCHHAR, Department of Math and Sciences, Kentucky State University, Frankfort, KY 40601.

During the course of evolution, plants have synthesized thousands of secondary compounds that are not essential to a plant's primary metabolic processes, but serve other adaptive roles. The use of the dried rhizomes of ginger plant, *Zingiber officinale* Roscoe (Zingiberaceae), as a medicinal agent is well established. The sesquiterpene hydrocarbons zingiberene and curcumene constitute a significant amount of the ginger rhizomes composition. The question arose as to whether other natural products might be found to have similar composition and antirhinoviral activity. Advanced techniques in isolation, purification, and characterization of natural product compounds are sophisticated undertakings. Owing to the complexity of the active ingredients in their extracts, commercial synthesis is likely to be impractical. In this study, crude extracts prepared from leaves of the wild tomato relative *Lycopersicon hirsutum f. typicum* (Solanaceae) were fractionated using an open glass chromatographic column containing alumina-II. Gas chromatographic and mass spectrometric analysis of the separated fractions produced molecular ions at m/e 204 and 202, which are consistent with the assignment of the molecular formula of the two sesquiterpene hydrocarbons zingiberene and curcumene, respectively. Our preliminary results have indicated that, two wild tomato accessions (PI-127827 and PI-127826) of

L. hirsutum f. typicum can be used as alternative source of zingiberene and curcumene. Concentrations of the two sesquiterpene hydrocarbons were determined per unit leaf surface area (mm^2) and per g fresh wild tomato leaves. An average three month old wild tomato accession of *L. hirsutum f. typicum* (PI-127827) has 333.7 g of leaves averaging about 31,261 cm^2 exposed leaf surface area (excluding plant stem surface area) and would produce 45.4 g of zingiberene and 17.6 g of curcumene.

HEALTH SCIENCES

Trace elements in tap water and stream water of eastern Kentucky. J. G. SHIBER, Division of Biological Sciences & Related Technologies, Prestonsburg Community College, Kentucky Community & Technical College System, Prestonsburg, KY 41653.

Prestonsburg Community College human ecology students and science faculty members collected water samples in spring 2001 from the kitchen taps of private homes and from selected locations along the Levisa Fork of the Big Sandy River. Two tap water samples per home were taken: one before daily usage and one after at least an hour of use. All samples were analyzed for As, Cd, Pb, Ni, and Cu, by plasma emission spectroscopy, and although none had concentrations of these elements that exceeded their respective maximum contamination levels (MCL), there is concern about the As, Cd and Pb detected in the samples. For As, there is an anticipated change for its MCL, from 50 ppb to between 3 ppb and 20 ppb, due to the 2001 National Research Council recommendations, resulting from research that has linked low As levels to certain cancers in humans. The concentrations found in the water samples here range from 10.0–33.0 ppb, suggesting a potential health hazard. Furthermore, the EPA has determined the MCL "goal" for Pb and Cd to be 0 ppb, and, in this study, the former ranged from 3.0–7.0 ppb, and the latter, from 0.2–1.0 ppb. Since so many people in this area drink their tap water (77% in this study), which comes from both municipal supplies emanating from the Big Sandy River/Levisa Fork and private wells, further more comprehensive and regular studies of these toxic elements in both tap and stream water of the area are advised.

Effective use of web forms for health survey data collection. ASHLEIGH HAYES, SUSAN TEMPLETON and MARTHA MARLETTE, Land-Grant Program, Kentucky State University, Frankfort, KY 40601.

The Internet is becoming a useful resource for collecting survey data. An online survey was conducted among high school students participating in an internship program (Research Extension Apprenticeship Program—REAP) on campus. An online survey was prepared using Microsoft® FrontPage® 2000. This survey contained 27 nutrition and activity level questions modeled after the 1999 Youth Risk Behavior Surveillance System. Multiple choice questions were presented as drop-down menus; yes or no questions were option buttons. A consent form required each participant to enter his or her password and ensured a respondent was not counted twice; a confirmation page gave participants feedback from the national sample. Advantages of using the online survey include low cost, quick response, and elimination of transcription errors. The response rate was only 80% because off-campus interns had limited access to the Internet. Results from the survey showed that REAP interns were similar to the national sample, with the following exceptions: REAP interns used dieting more (68% vs. 40% national) and exercising less (50% vs. 58%) for weight control. The REAP interns were more likely to consume juice, salad, potatoes, and carrots, and less likely to consume fruit and milk at least once a day. The REAP interns were more likely (59 % vs. 35%) to have hard exercise less than 3 days a week and more likely (71% vs. 42%) to watch TV more than three hours a day. This survey suggests that the Internet can be an effective tool for collecting specific health data from target populations.

Pawpaw products receive favorable taste ratings. SUSAN B. TEMPLETON and MARTHA MARLETTE, Land-Grant Program, Kentucky State University, Frankfort, KY 40601.

Consumed as fresh fruit, the pawpaw has a short shelf-life, only 2–3 days at room temperature and up to three weeks with refrigeration. There is commercial processing potential for pawpaw pulp in juices, ice cream, baked goods, etc. Consumer acceptability of such products needs to be investigated. One hundred and five attendees of the 2nd Annual Pawpaw Field Day held at the Kentucky State University Research Farm participated in a tasting of selected pawpaw products. Items were rated on a scale from 1 = "Liked it extremely" to 7 = "Disliked it extremely." Fifty-six percent of tasters were male; 58% were 41–60 years of age. Only 72% of tasters had previously eaten pawpaw. Pawpaw ice cream was the best received item (55% of tasters liked it extremely), followed by pawpaw cake with lemon icing, liked extremely by 45%. The pawpaw/grape juice drink was liked extremely by 31% of participants. Plain pawpaw butter was liked extremely by 26% of tasters; pawpaw butter prepared with lemon and grape juice was liked extremely by 11%, while the version prepared with orange and lemon was liked extremely by only 8%. Custard prepared from select pawpaw fruit was liked extremely by 42% of tasters, while the custard prepared from seconds was liked extremely by only 16%. The gender and age of participants had little influence on their acceptance ratings. However, as this group of tasters may be predisposed to accepting pawpaw products, further evaluations should be conducted with participants from varying age and ethnic groups in more neutral settings.

Food choices of 6th grade students. MARTHA MARLETTE and SUSAN TEMPLETON, Land-Grant Program, Kentucky State University, Frankfort, KY 40601.

A number of health problems in later life, such as cancer, diabetes, heart disease, obesity, and osteoporosis, are

of nutritional origin. According to recent national surveys, energy, calcium, and folate intakes of school-aged children fell below recommended levels around age ten and tended to remain inadequate thereafter. Over 76% of students surveyed nationally in the Youth Risk Behavior Survey System ate fewer than 5 servings of fruits and vegetables daily and 82% drank fewer than 3 glasses of milk daily. Focus groups were conducted in three local schools to explore factors that influence food choices of sixth graders. The 26 focus group participants also completed a questionnaire about food choice factors and food-related behavior at home. Eight males and 18 females, ages 11–13, participated. Factors most frequently reported as "Very Important" were taste (18 out of 26) and hunger or cravings (14). Factors most frequently reported as "Not at all important" were incentives (16) and cultural influences (14). Less than half of these sixth graders reported taking part in household menu planning (12), grocery shopping (12), and meal preparation (8). Fourteen students responded they sometimes or often spend their own money for food, drinks or snacks. When asked about their past 24-hour intake, these children reported a mean of 8 home-prepared items, 2 fast-food items, and less than 1 convenience food item. These children also reported consuming a mean of 5 snack items in the previous 24 hours. Intensive nutrition education is needed for school-age children.

MATHEMATICS

Binomial theorem analogues. JAMES B. BARKSDALE, JR., Department of Mathematics, Western Kentucky University, Bowling Green, KY 42101.

This presentation discusses and illustrates several families of polynomial functions which satisfy binomial theorem analogue formulas. Elementary, developmental details are implemented in order to establish several analogue theorems, including those of Vandermonde, Norlund, and Schlafli, which are fundamentally central in several areas of mathematics. These presentation concepts could also serve very suitably as enrichment themes (or as special project topics) to be used in the teaching of undergraduate mathematics courses.

PHYSIOLOGY & BIOCHEMISTRY

Analysis of skeletal development on the basis of body mass and bone resorption. D. L. DeMOSS, Department of Biology, Morehead State University, Morehead, KY 40351; and G. L. WRIGHT and W. D. GENG, Department of Physiology, Marshall University School of Medicine, Huntington, WV 25704.

Regression analysis was utilized to define the relationship among body weight, whole skeleton bone resorption (^{3}H-tetracycline method), and the development of skeletal mass. The results indicated that skeletal development (% body weight) of slowly growing, 24-week-old rats consisted of two major components, one directly ($r = 0.985$, $P < 0.001$) and one inversely ($r = 0.977$, $P < 0.001$) related to body weight. It was further noted that the skeletal resorption rate was inversely correlated to body weight ($r = 0.879$, $P < 0.05$) and directly related to skeletal development ($r = 0.865$, $P < 0.05$), suggesting that whole skeleton bone resorption and formation were highly correlated in the slowly growing animal. A third, small component of skeletal development, identified from the analysis of data of 24-week-old animals, indicated no direct relationship to either body weight or resorptive activity. The model presented enables the separation of skeleton mass into major components which may represent mechanically and metabolically driven bone formation.

Determining the immune system's role in a mammalian energy budget. STEPHEN COMPTON and TERRY DERTING, Department of Biological Sciences, Murray State University, Murray, KY 42071.

The amount of energy required to maintain a functioning immune system and mount an immune response was studied in wild white-footed mouse, *Peromyscus leucopus.* I tested the null hypotheses that 1) the energy cost of maintaining a functioning immune system is not a significant energy demanding process, 2) there is no significant energetic cost of mounting an immune response, and 3) other systems of the body are not affected by changes in the immune system. To determine the amounts of energy used, daily metabolic rate (DMR), resting metabolic rate (RMR), and the masses of vital organs were measured. The energy required to maintain an immune system was studied by comparing a control group to a group that was immunosuppressed. There were no significant differences found in the DMR, RMR, or organ masses between control and experimental mice. To measure the energetic cost of mounting an immune response, control mice were tested against mice injected with sheep red blood cells (SRBC) and phytohemagglutinin (PHA) to stimulate the humoral and cell-mediated components of the immune system, respectively. There were no significant differences in DMR or RMR between groups; however, both the wet and dry masses of the small intestine and testes were significantly lower in the SRBC-PHA-treated mice. My findings suggested that maintaining a functioning immune system was not a significant energy demanding process. Mounting an immune response, however, was a significant energy demanding process that necessitated trade-offs in allocation of energy within the organism.

SCIENCE EDUCATION

The environment tomorrow. JOHN FRAZIER and J. G. SHIBER, Division of Biological Sciences & Related Technologies, Prestonsburg Community College, Prestonsburg, KY 41653.

A survey of 578 students from four eastern Kentucky secondary and post-secondary schools regarding their concern for the environment was conducted in the spring of 2001. Two hundred thirty-nine college and 339 high school students comprised the total sample. Their responses to the ten multiple choice and one subjective

questions indicated that students in this region claim they would like to be more environmentally responsible; but, for lack of knowledge or enthusiasm, or both, are not. Most of the 38% who said they were very concerned were college students and most of the 62% who had little or no concern for the environment were high schoolers. Eighty-eight percent of all respondents said they either never or only occasionally consider the environment when making purchasing decisions while shopping and 76% confessed their lifestyles are rarely governed by a concern for the environment. Sixty-six percent said they either can't afford, or don't have the time, to be environmentally responsible; but 87% said that, if they knew what to do and had the time and resources, they would be. When responding to the question about what they would change in their lifestyles, if they had the time and resources to do so, the majority of the students chose things that do not require much, if any, additional expense. It is concluded that what students of our region need is more knowledge about environmental matters. It is suggested that high school curricula include a mandatory course in environmental science or human ecology which would be a prerequisite for graduation.

ZOOLOGY

Odor cues and their role in the assessment of genetic quality in the monomorphic species, *Mus musculus*. LEE WEBB and TERRY DERTING, Biological Sciences Department, Murray State University, Murray, KY 42071.

The "good genes" hypothesis of mate selection proposes that females make mate choices based on the genetic quality of their potential mates. Research suggests that mate preferences in monomorphic species are based primarily on the odors of potential mates. These odors may display genetic information that signals the quality of a mate. Using the monomorphic house mouse, *Mus musculus*, I paired mice based on female odor preference to determine whether this preference would affect offspring quality. My null hypotheses were that 1) female odor preferences are not correlated with the fitness of their offspring and 2) the attractiveness of male odors is not related to their hormonal status. My results indicated that the number of placental scars was significantly greater in females paired with males with preferred odors compared with those paired with males with non-preferred odors, which may signify higher potential litter sizes for females paired with males whose odors they preferred. Wet masses of the caecum, colon, and adrenal glands and dry mass of the testes were significantly larger in sons sired by males with preferred odors in contrast to those sired by males with non-preferred odors. Testosterone and corticosterone levels did not differ significantly in males or their sons. Overall, my findings weakly supported the "good genes" hypothesis. They showed a marginal relationship between female mate preference and offspring quality. Similarities in the olfactory systems of the human and mouse suggest that these structures are not vestigial and may play an important role in human behavior.

Habitat selection of hatchling spiny-tailed iguanas (*Ctenosaura pectinata*) based on predation risks. KATHARINE BENDELE and RICHARD D. DURTSCHE, Department of Biological Sciences, Northern Kentucky University, Highland Heights, KY 41099.

Mexican spiny-tailed iguanas (*Ctenosaura pectinata*) are polymorphic in both size and color, and occupy different microhabitats based on their ontogenetic stage. Hatchling iguanas are completely green and easily stand out in microhabitats that are not predominantly green. We hypothesized that the hatchlings were more likely to avoid predator attacks in some microhabitats than others. To test this hypothesis, we monitored plasticene models of the hatchlings placed in six different microhabitats (ground, grass, shrub, tree, rock, and burrow) in central Mexico. Moreover, because hatchlings are found gregarious in their use of certain microhabitats, we tested whether these behaviors decreased the risk of predation for the individual. The plasticene color was matched as closely as possible to that of the lizards using a spectrometer to determine the appropriate mixing of various clay colors. Models were scented daily with hatchling odors by swabbing with a solution of cloacal secretions. Results indicate that the rate of predation was greatest in microhabitats where hatchlings spend little of their time. Furthermore, placement of models in gregarious versus individual positions within microhabitats demonstrated that predator attacks were not different between the two groupings, but that individual survival rates were increased in the gregarious setting.

Time activity budget for the American toad *Bufo americanus*. TAYA C. DICKMAN and RICHARD D. DURTSCHE, Department of Biological Sciences, Northern Kentucky University, Highland Heights, KY 41099.

American toads (*Bufo americanus*) are early spring breeders in northern temperate climates and lay their eggs in ephemeral ponds. Optimizing behavioral activities (e.g., foraging) for maximal growth of toad tadpoles, therefore, would be expected for this species to reach metamorphosis prior to pond desiccation. Prior behavioral studies on toad tadpoles have focused on responses to predators and food resources under laboratory conditions, but little is known of diel activity patterns under natural conditions. We conducted focal samples on *B. americanus* tadpoles inhabiting ephemeral ponds in northern Minnesota in May and June of 2001. Time activity budgets were created for tadpoles throughout all periods of the day. Nine activities were identified. These were evaluated within the context of microhabitat use and solar exposure. Feeding behavior was examined through observations of duration, frequency, and food substrate. Data from these observations were used to estimate mean time spent per activity. Non-moving behaviors made up 65.6% of the tadpoles' activities. Feeding comprised 18.4% and moving 7.6% of their daily period. A combination of other activities such as air gulping, predator escape, schooling, social interaction, and squiggle behavior comprised the remaining 8.4%. The majority of activity bouts (88%) were less than

65 seconds and 92% of the distances moved by tadpoles were less than 40 cm. Comparisons were made between activity time and period of the day to determine if temporal activity patterns exist. These analyses suggest daily trends in certain behavioral activities and not in others.

The effect of invasive plant species on the biodiversity of herpetefauna located at the Cincinnati Nature Center. NICHOLAS L. McEVOY and RICHARD D. DURTSCHE, Department of Biological Sciences, Northern Kentucky University, Highland Heights, KY 41099.

Amur honeysuckle, *Lonicera maackii,* is an Asian woody shrub that has accomplished a recent spread throughout the eastern United States. Despite a documented life history pattern of this plant, no studies have been performed to determine the effect of this exotic plant on the native herpetefauna. The goal of this study is to determine if the invasion of exotic plant species, especially *L. mackii,* has a significant effect on the biodiversity and abundance of the native herpetefauna. The Cincinnati Nature Center has recently documented the invasion of exotic plant species, including *L. maackii.* In addition to this, much of the wildlife found within the Cincinnati Nature Center, especially the herpetefauna, remain undocumented. With the assistance of vegetation abundance mapping, areas of the Cincinnati Nature Center were termed as "highly invaded" with *L. maackii.* Plots for collection of herpetefauna were organized within these areas throughout the Cincinnati Nature Center along with corresponding plots in "non-invaded" areas. Various collection techniques, primarily haphazard sampling, were used in collection of the organisms. Preliminary results suggest that there is no significant difference in the biodiversity or abundance of the herpetefauna found in the "highly invaded" and "non-invaded" plots within the Cincinnati Nature Center.

Diet comparison in three tadpole species, *Rana sylvatica, Bufo americanus,* and *Pseudacris crucifer,* in a northern temperate climate. JENNIFER K. QUAMMEN and RICHARD D. DURTSCHE, Department of Biological Sciences, Northern Kentucky University, Highland Heights, KY 41099.

The natural diet of northern temperate tadpoles is a largely neglected area of study. We investigated the natural diets in three anuran larvae, the wood frog (*Rana sylvatica*), the American toad (*Bufo americanus*), and the spring peeper (*Pseudacris crucifer*) from several ephemeral ponds in northern Minnesota. Previous laboratory studies suggest that these species, as well as others with similar mouthparts, are suspension or filter feeders. Our results suggest that all three species are active grazers upon the aufwichs (periphyton) or material found on aquatic vegetation and submerged substrates. The diet of these tadpoles is comprised primarily of detritus, 73.3% in *B. americanus,* 73.9% in *R. sylvatica,* and 82.1% in *P. crucifer.* Prior investigators suggest that *R. sylvatica* tadpoles are facultative predators on *B. americanus* tadpoles resulting in differential breeding pond selection by adult *B. americanus.* Our study confirms this separation of tadpole populations. The ephemeral ponds used for collections had a clear distinction between *R. sylvatica* and *B. americanus* tadpole populations. However, ponds with *R. sylvatica* also had an increased overall tadpole diversity, including two smaller *Pseudacris* species, while *B. americanus* appeared to be the sole tadpole species in the ponds it inhabited. Of the invertebrate food in the diets, significantly greater percentage was found in *R. sylvatica* than in the other species, lending support to their suggested predacious feeding behavior. The remainder of the identifiable organic foodstuffs were counted and analyzed to find possible interspecific trends.

J. Ky. Acad. Sci. 63(1):74. 2002.

BOOK REVIEW

Irwin M. Brodo, Sylvia Duran Sharnoff, and Stephen Sharnoff. 2001. Lichens of North America. Yale University Press, New Haven and London. xxiv + 795 pages; illus. ISBN 0-300-08249-5. $75.00.

Reviewing this book without using superlatives is difficult, so I shall go ahead and use them. Descriptors that come immediately to mind are extraordinary, magnificent, and dazzling. This is the finest work yet published on North American lichens. The person who described it as "the twenty-first-century lichen equivalent of Audubon's *Birds of America*" was right on the mark. If a book is good, or in this case much more than just good, the reviewer should praise it and describe its contents briefly, and then stop. I shall do just that. *Lichens of North America* is its own paean.

Part One, "About the Lichens," considers just about everything that one might wish to know about these entities: What lichens are and are not, thallus shapes and structure, reproduction, colors, physiology, growth, chemistry, lichens and ecosystems, geographic distribution of lichens in North America, lichens and people, environmental monitoring with lichens, naming and classifying lichens, and collecting and studying them. Part two, "Guide to the lichens," includes 28 pages of identification keys to genera and major groups and then, as the largest section of the book (pages 117–749), descriptions, illustrations, keys to over 800 species that are "most common, conspicuous, or ecologically significant," and range maps. The volume closes with a 10-page glossary, a 5-page "Further reading and bibliography," and a 25-page index of names.

Each generic account includes a generic description, a key to included species if more than one, descriptions of species (including brief comments), and range maps. More than 800 species are treated in full. Many species not considered in detail are mentioned in the comments. An innovation is the inclusion of vernacular ("common") names for most genera and species, many of the names coined for this book. The keys to genera and major groups are not for the faint of heart or for those without optical equipment and the needed chemicals (at least for those lichens I chose to test, they work). The spectacular color photographs, approximately 940 from all parts of the United States and Canada, are the particular glory of the work. Never have lichens been better presented. Owning the volume for the photos alone cannot be faulted.

The book's vital statistics are impressive. It has nearly 800 pages, most with illustrations; it weighs about 9 pounds; its dimensions are approximately 11 × 10 × 2 inches. Truly it can be described as a ponderous tome. This splendid and authoritative work will perhaps increase interest in North American lichens, a relatively neglected group. It has already done so with one of my students. Irwin Brodo is researcher emeritus at the Canadian Museum of Nature. Sylvia Duran Sharnoff and Stephen Sharnoff traveled throughout the United States and Canada taking the color photographs. Brodo, the Sharnoffs, and Yale University Press have produced a masterpiece.

John W. Thieret
Department of Biological Sciences
Northern Kentucky University
Highland Heights, Kentucky 41099

J. Ky. Acad. Sci. 63(1):75–86. 2002.

APPENDIX

The mission of the Kentucky Academy of Science is to encourage scientific research, promote the diffusion of scientific knowledge, and unify the scientific interests of the Commonwealth of Kentucky. This is accomplished, in part, through programs sponsored and encouraged by the Junior Academy of Science.

The Junior Academy holds a meeting annually at which precollege students have the opportunity to share their experiences in investigative science with their peers and with more seasoned science educators and scholars. This meeting provides an excellent opportunity through which KAS fulfills a portion of its mission by ratifying the efforts of these fledgling scientists and acknowledging their accomplishments.

The *Journal* also plays a role in this process by broadening the exposure afforded these initial experiences in scientific investigation. In this section, sample abstracts from last year's Junior Academy program are presented. Please share with us the celebration of these early steps in science by the students whose work is summarized here. The Editorial Board of the *Journal* takes this opportunity to congratulate these students and their mentors. In addition, on behalf of the Academy's Governing Board, we encourage you to help advance the Academy's mission and to assist these student efforts by providing your encouragement and, if possible, mentorship in the development of projects and in the written and oral communication of project results.

Raymond E. Sicard, Ph.D.
Editor

Abstracts Submitted from the 2001 Kentucky Junior Academy of Science Meeting

Edited by Robert J. Barney

BEHAVIORAL & SOCIAL SCIENCES

The effect of rap and classical background music on math and reading comprehension test scores of high school students. CHRIS BISCHOFF, duPont Manual High School, 120 W. Lee St., Louisville, KY 40208.

This study was conducted to determine the effect music might have on academic testing. The idea was to determine if listening to classical or rap music while performing math and reading comprehension tests would increase or decrease performance of high school students. The test group consisted of high school sophomores (n = 30) with ages ranging from 14 to 16 and gender having an equal representation. The testing situation was identically replicated for each subject. Classroom setting, individual headsets, preset volume, preset music selection and timed test were repeated for all. Three types of listening styles were tested: rap, classical and no music. Two types of tests were used, math and reading comprehension, each consisting of 10 questions. The data obtained during this study showed the control group, which had no music, scored an average of 87% on math and 71% on reading comprehension. Results from those exposed to classical music were 90% on math and 74% on reading comprehension. Those who listened to rap music scored an average of 88% on math and 59% on reading comprehension. This study clearly shows the effect these forms of music have on test performance. Listening to classical or no music while performing math and reading comprehension tests had little or no significant effect on tests scores. Listening to rap music had little or no effect on math scores but severely decreased performance on reading comprehension tests.

A study of individual differences in theories of intelligence in high school students and teachers. EMMA ESSOCK-BURNS, duPont Manual High School, 120 W. Lee St., Louisville, KY 40208.

The purpose of this study was to better understand theories of one's self concerning both fixed and malleable intelligence in relation to development and confidence. Scholastically targeted high school age students were assessed on their intelligence self-theories which was compared to confidence level, goal orientation (performance or learning), and preferred subject area. A questionnaire gauging intelligence theory (entity/fixed or incremental/malleable) on a "changeability" and "ability" scale was administered to 186 high school students. Responses were related to "goal" (learning or performance oriented), "intellectual-confidence," "preferred subject" (Math/Science or English), gender, major, and year. A similar questionnaire was administered to 29 teachers with "failure" (likelihood of student not attempting a challenge after failure)

and "success" (likelihood of student re-attempting a challenge after teacher's entity-trigger praise) measured in relation to the subject and year taught. Students tended more toward entity as they got older (mean ability ranking: freshmen = 39%, seniors = 60%); yet girls were more incremental than boys (mean changeability ranking: girls = 4.3, boys = 4.1) and art was the most incremental major (mean changeability ranking: art = 4.57, math/science/technology = 4.00, high school university = 4.00). Intellectual self-confidence differed in sophomore year (mean changeability ranking: girls = 4.7, boys = 5.5), coinciding with the girls' highest entity thinking year, supporting Dweck's "helpless pattern." Student intelligence theory matched that of their preferred subject area teacher, possibly reinforcing each other. This study supports the idea that people retain specific intelligence theories, which continue to affect various facets throughout high school. Therefore, can these theories be targeted and changed with external stimuli creating a more sound and enriching persona?

A study of the effects of exercise on the symptoms of seasonal affective disorder. JILLYAN HARLAN and LISA MUDD, Math/Science/Technology Magnet, duPont Manual High School, 120 W. Lee St., Louisville, KY 40208.

Seasonal affective disorder (SAD) is a condition in which people seem to weaken during the colder months of the year. Its characteristics include a lack of energy and the ability to concentrate, increased appetite, hypersomnia, and withdrawal from family and friends. A study was conducted to find whether exercise has an effect on SAD. This study surveyed 104 athletes and 104 non-athletes about their emotional and physical observations between the months of November and April. After analyzing the data, it was found that 67.86% of non-athletes experience the effects of SAD while only 43.14% of athletes experience these same effects. Therefore, it was shown that exercise does have an affect on the symptoms of SAD in students.

The effect of time interval between sleeping and learning on memory retention. NGOCUYEN V. NGUYEN, duPont Manual High School, 120 W. Lee St., Louisville, KY 40208.

Behavioral studies have made it known that permanent memories are not created at the instant they are acquired. Rote rehearsal allows information which has remained in short-term memory long enough to be transferred into long-term memory, through coding processes. There are many theories involving the role REM sleep plays in the consolidation of long-memory, known to be stored in the cerebral cortex. Numerous factors have been known to affect memory retention, including sleep. This experiment was designed to test the effect of the interval between study and sleep on long-term memory retention. Four female subjects within the same age range were asked to participate for five nights. For each night, each was given a list to study and directed to get to bed at a specified interval after their study time. It was hypothesized that a shorter interval will result in better memory performance. The hypothesis was not supported by the results of the experiment. There are many variations between data gathered from each subject and inconsistency in pattern, which suggests errors. The experiment also proposed amount of sleep as a possible influencing factor on subjects' performance, but this was not supported either.

A study of speech discrimination in children with Williams Syndrome. JENNIFER TINDLE, duPont Manual High School, 120 W. Lee St., Louisville, KY 40208.

This project was designed to determine if Williams syndrome children discriminate speech sounds like normal functioning people. Williams syndrome is a genetic disorder caused by a deletion on the 7th chromosome. A symptom of this disorder is mild mental retardation and often attention disorders. People with Williams syndrome often experience other medical problems such as heart problems and heightened sensitivity to sound. The participants were tested by having them listen to two speech sounds, /ba/ and /ga/, 40 times each.The child wore a geodesic sensor net (124 electrodes) on their head to record the brain activity. While the stimuli were being presented the child's brain waves were being recorded using the net station. After the data were analyzed it was found that the Williams syndrome children analyzed the sound similar to normal functioning children, but at a slower rate.

Daily activity of *Tenebrio molitor* beetles. SHANNON TURNEY, Notre Dame Academy, 1699 Hilton Drive, Covington, KY 41011-2796.

It is very difficult to monitor the motion of *Tenebrio* adults because the insects live in the dark. The purpose of this experiment was to measure the activity of the *Tenebrio* without using light. A Hall effect probe, used to monitor changes in a magnetic field, can detect movement of a magnet. Small chips of magnets were glued onto the backs of several *Tenebrio* adults. Individual adults were then placed, along with the probe, some bran, and a small piece of potato for moisture, into a small chamber consisting of a film tube with a hole in the side to position the probe. The Hall effect probe was interfaced to a computer and the magnetic field was monitored for 24-hours. The times when there were changes in the magnetic field corresponded to periods of motion. This made it possible to track the *Tenebrio* without using light. The *Tenebrio* adults were active approximately 31% of the time, 50% of which were between the hours of 8 pm and 1 am, when the insect was most active. The lower points of activity were between 6 am and 10 am. This supports the common claim that the beetles are nocturnal.

Electrophysiological indicators of phonetic discrimination in human infants. WILLIAM ROBERT USELTON III, Science Department, Louisville Male High School, 4409 Preston Highway, Louisville, KY 40213.

The purpose of this longitudinal study was to replicate

and extend previous studies to see if the infant brain can discriminate between various computer-generated consonant-vowel speech sounds and use the data to see if one can predict a person's ability to acquire language within 48 hours of birth. Seventy-six infants, from the Kosair Children's Hospital nursery, were recruited for testing through parents' permission. Testing involved playing the speech sound (ba, da, ga, bu, du, and gu) while the infant lay in a crib. While the stimulus was playing, a 128 channel geodesics sensor net, a very sensitive apparatus, recorded the ongoing EEG and the infant's brain response. Once the procedure was completed, the net was removed and the data analyzed. EEG files were segmented, averaged, baseline-corrected, and submitted to principal component analysis and analysis of variance. The results were in agreement with the previous studies and indicated that the infant brain reliably discriminates between various consonants and vowels ($p < 0.0001$). The next step will involve using the patterns of electrical brain activity in response to the sounds to predict a person's ability to acquire language.

BIOLOGICAL TOPICS

The effects of biobooster chemicals on the denitrification of water. EVAN BOYER and BRIAN GOODIN, duPont Manual High School, 120 W. Lee St., Louisville, KY 40208.

A test was conducted to determine which biobooster chemical lowered the amount of ammonia and nitrite fastest. This has applications in aquaculture (the growth of aquatic species in contained systems) for determining the best chemical to use when growing species in recirculating systems. Aquatic species continuously raise levels of these toxic chemicals with their waste, so a way of disposing of the chemicals is needed. Twelve samples of water containing 3 ppm ammonia were set up and air was pumped through the containers for 2.5 weeks. Three samples (the control) contained no ammonia-lowering chemicals, three contained *Freshwater BioBooster*, three contained *Bacta-Pur*, and three contained *Zeolite*. All of these chemicals were said to lower the levels of ammonia and nitrite faster than an environment not using any chemicals at all. Over the test period, ammonia, nitrites, and nitrate levels were determined using standard tests. It was found that *Bacta-Pur* lowered the levels best, followed by *Freshwater BioBooster*, *Zeolite*, and finally the control group. All chemical companies were correct in claiming they lowered the levels of chemicals faster than an environment without the chemical, but *Bacta-Pur* was most effective and is, thus, better suited for use in aquaculture.

The effect of status epilepticus on the GABAergic synaptic activity in the hippocampal formation of the brain. SUZANNE N. BRYCE, duPont Manual High School, 120 W. Lee St., Louisville, KY 40208.

Status epilepticus is a condition that plagues nearly 200,000 Americans every year. Although this is a prevailing disease, minimal research has been done on the effects of status epilepticus, what causes it, and how it can be prevented or cured. GABAergic neurotransmission in the hippocampus of the brain is believed to play a major role in termination of status epilepticus seizure activity. This experiment was conducted to determine whether the GABAergic activity increases or decreases during status epilepticus. It was hypothesized that the GABAergic activity in the hippocampus would increase during seizure activity. The tests were run on adult male, white Wistar rats. They underwent surgery to implant stimulating and recording electrodes in their brains. One week following this surgery, status epilepticus was induced on those animals which were to have their hippocampal tissue processed as "status" cells. Only animals which demonstrated predetermined ictal activity were used in the study. Tissue from both the "status" group and the control group was perfused and processed for GABA immunoreactivity. The number of GABAergic synapses for each group was quantified. It was determined that the total number of GABAergic synapses in the 98 control cells (305) greatly exceeded the total number of synapses in the 98 status epilepticus cells (268). The average number of GABAergic synapses per control cell was 3.1, while the average per status epilepticus cell was 2.7. It can be concluded that, instead of increasing, neural activity in the hippocampus decreases during status epilepticus, possibly because of the excitatory changes on the cell somas during the seizure activity.

The implications of age in relation to the hand development of string musicians. ERIN FINGER, duPont Manual High School, 120 W. Lee St., Louisville, KY 40208.

Dedicated musicians who learn to play stringed instruments early in childhood often develop growth abnormalities in their hands due to repetitive motions and stretching of their fingers. To determine if learning advanced techniques at a young age affects hand growth of musicians by causing abnormal development and increasing risk for repetitive strain injuries, an experimental group of 75 string musicians and a control group of 75 people who did not play string instruments were questioned. The survey population of musicians who played string instruments began playing their instruments at different developmental stages. Seventy-five percent of musicians who began playing under age 6 noted abnormalities in development of their hands compared to 16% of musicians who began at age 11. Fifty-one percent of musicians who started playing before the age of 10 experienced injuries. Learning advanced string instrument techniques at an early age is detrimental to the physical development of hands by causing growth abnormalities which can cause and aggravate repetitive strain injuries. Implications are that established methods like the Suzuki method may be better focused on the theory, musicality, and ear-training necessary for musical accomplishment, rather than advancing rapidly to a difficult repertoire that requires unusual stretching and hand movement before the joints and tendons are fully

developed. This will ensure that the body of the child is physically ready for the stretching involved in playing a stringed instrument and will decrease the risk of music-related repetitive strain injuries when the musician is older.

Change in placebo effect by diagnostic criteria in acute mania. ASHLEIGH HARDIN, Seneca High School, 3510 Goldsmith Lane, Louisville, KY 40220.

Bipolar I disorder, also known as manic-depressive disorder, is a mental illness in which the sufferer experiences extreme lows (depression) and extreme highs (mania or euphoria). It affects 1% of the U.S. population and is believed to be caused by genetic, environmental, and biochemical factors. The criteria used in diagnosing mania have changed over time. I have found that factors such as the length of trials, the source of funding, and possible lithium immunity also affect a change in the placebo effect. I researched several different studies of acute mania in which subjects were treated with either lithium, a placebo, or both. I also noted what methods the researchers used in diagnosing mania: RDC, DSM-III, or DSM-IV. I then tabled this information and found the mean of each method's response rate for both lithium and placebo. I found that placebo response was higher for RDC and DSM-IV methods. In addition, the lithium response rate was higher for DSM-III than for the others. I conclude that RDC and DSM-IV criteria are more compatible but may not be strict enough to prevent a relatively high placebo response.

Leukocyte surface expression of human HLA B-27 transgene in rats. STEPHANIE LOGSDON, Seneca High School, 3510 Goldsmith Lane, Louisville, KY 40220.

The HLA B-27 gene in humans is directly linked with development of inflammatory diseases, spinal arthritis, immune disorders, and organ transplant rejection. The factors that influence the onset of the severity of the manifestations of the disease are unknown. Transgenic rats are a model of irritable bowel syndrome, and these unknown factors were investigated through the transgenic rats and their progeny of hybrid background strains. If the factors that control aspects of the disease are found, ways to manipulate them to slow the onset of the disease and reduce the severity of it can be developed. The success of inserting a B-27 transgene into a non-transgenic strain of rat has never been attempted to date, so adverse effects to the fetus could result. Transmission of human HLA B-27 transgene in each of two female rats was followed through one generation. Factors that may influence cell surface expression of this transgene were studied, such as fetal survival, gender, and age differences among the progeny. Rats were mated with a non-transgenic strain of brown Noway rat. All rats with the transgene are affected by the age of six months, but the severity of manifestations of the disease varies. Since the time to manifest disease exceeds the duration available for this project, we used cell surface expression of the HLA B-27 protein on rat leukocytes as a surrogate marker of transmission, since greater expression correlates with earlier onset of the disease. I sought to study factors that may alter leukocyte surface expression of the transgene in progeny of matings between transgenic and normal rats. Analyses included the proportion of rat pups that receive the transgene and the intensity of its expression on leukocyte surface. From the resulting data, it can be concluded that the B-27 gene can be successfully entered into a non-transgenic strain of rat without harm to the fetus. Also, the data shows that the intensity of the transgene expression, and therefore the disease itself, is not age-dependent but gender-independent. Ongoing studies are being performed presently to test the effects of other rat genes on expression of the transgene.

The effect of magnetism on foot warmth during winter exercise. JESSICA H. LOWELL, duPont Manual High School, 120 W. Lee St., Louisville, KY 40208.

The purpose of this experiment was to test the impact of magnetism on warmth and comfort in cold weather. It was hypothesized, for reasons outlined in the main section of the paper, that magnetism would not have a significant effect. The sample consisted of nine members of Team Louisville Bicycle Club, a competitive amateur cycling team. Each subject wore either a magnet or a placebo on each foot during two training rides in December or early January. The magnets were attached with Velcro to the insides of the "booties" worn by the cyclists. Each subject completed a response form evaluating the effects of their magnets. Three tests showed significant results—a test of the effects of north-seeking magnets worn during the first ride, a test of the linear relationship between outside temperature and the placebo effect, and a test of the effects of north-seeking magnets worn on the left foot. I offer several possible explanations for the results. One was that north-seeking magnets actually stimulate tissue, as stated by magnetic therapists. Another was that the primary orientation of the cyclists affected the magnets.

The effectiveness of selective serotonin re-uptake inhibitors on obsessive-compulsive disorder. STEPHANIE L. LUCKETT, Seneca High School, 3510 Goldsmith Lane, Louisville, KY 40220.

Obsessive-compulsive disorder (OCD) is an anxiety disorder which causes a person to have recurring thoughts (obsessions) and/or compelling feelings to perform ritual acts (compulsions) repeatedly. The disorder affects approximately 1.2 million people in the U.S. and is ranked in the top five metal illnesses in the U.S. Low levels of the neurotransmitter serotonin are predicted to be the cause of this illness. Current treatments for OCD are usually a combination of pharmaceutical medications and/or behavior therapy. Pharmaceutical medications include Prozac®, Luvox®, Paxil®, Zoloft® (all selective serotonin re-uptake inhibitors—SSRI), and Anafranil® (a tricyclic antidepressant). I limited my study to SSRIs. After gathering previously done research results and analyzing the

data it has been found that none of the medications have a greater or lesser affect on the patients and that all have proved to work equally well.

Inhibition of ribonucleoprotein enzyme telomerase correlates with antiproliferative activity of guanosine-rich oligonucleotides. NIKHIL MIRCHANDANI, duPont Manual High School, 120 W. Lee St., Louisville, KY 40208.

Telomerase uses the RNA component of its ribonucleoprotein enzymatic structure as a template to synthesize telomeric DNA (TTAGGG)n directly onto the ends of chromosomes, thus stabilizing telomeres that protect the ends of chromosomes from degradation and preventing cellular senescence. This study explored the use of guanosine-rich oligonucleotides (GROs) as agents for inhibiting cancerous cell growth through elimination or downregulation of the enzyme telomerase. In the first successful experimentation of its kind, immunofluorescent labeling procedures were used to locate telomerase in cancerous cells. DU 145 (prostate), PZ, CA, and MDA (breast) tumor cells were exposed to modified oligonucleotides GRO 29A and GRO 15B and 4% paraformaldehyde in phosphate-buffered saline (PBS), then washed. Cells were blocked with 5% goat serum in PBS and incubated overnight with anti-telomerase primary antibody at 1:50, 1:100, 1:200, 1:400, and 1:800 concentrations at 4°C. The cells were then placed in a humid chamber, washed, and incubated with secondary antibody in concentrations corresponding to the concentrations of the primary antibody. Cells were finally washed and mounted for viewing. It was found previously that GRO 29A had a potent growth-inhibitory effect on tumor cells. Immunofluorescent labeling showed that GRO 29A also decreased expression of the enzyme telomerase, while GRO 15B and PBS did not. This suggests that the antiproliferative activity of G-rich oligonucleotides correlates with inhibition of telomerase, possibly through direct binding.

The isolation and identification of rat neuroglobin cDNA using PCR and DNA sequencing. SUPRAJA PARTHASARATHY, duPont Manual High School, 120 W. Lee St., Louisville, KY 40208.

This project was conducted to determine if a protein that carries oxygen to the brain, neuroglobin, was present in rat brain. Finding neuroglobins in rat brain may lead to advances in medications and research for brain related diseases such as stroke and Alzheimer's disease, because rat brains are one of the best models to use in brain research. Neuroglobin cDNA was isolated and identified in a rat brain cDNA pool using polymerase chain reaction (PCR). Putative neuroglobin cDNA was ligated with a bacterial plasmid called p-GEM T-easy vector and inserted into competent bacteria (DH5α) which were grown in optimum conditions. DNA was isolated from the bacteria and results showed that rat brain has neuroglobin. The neuroglobin cDNA contains 456 bases coding for 151 amino acids, starting with ATG (methionine) and ending with TAA (stop codon). The nucleotide sequences in mouse is 96.7% and in human is 94.7% similar to the rat nucleotide sequence. The amino acid sequences in mouse is 96.7% and in human is 87.7% similar to that of the rat. In conclusion, this finding of rat brain neuroglobin may help advancement towards new medications and treatments for brain related diseases.

Arteriole dimensions and aging: mechanisms of orthostatic hypotension. SUDIP K. SAHA, duPont Manual High School, 120 W. Lee St., Louisville, KY 40208.

First order arterioles were isolated from the cremaster muscle of aged (n = 12) and young (n = 19) male rats. The arterioles were treated with varying concentrations of norepinephrine to ascertain constrictor responses. Step changes in pressure (0–170 cm H_2O) were performed in a calcium-enriched solution to measure the active curve. Varying concentrations of acetylcholine and adenosine were used to measure dilator responses. Step changes in pressure (0–190 cm H_2O) were performed in a calcium-free solution to measure the passive curve. Both aged and young rats showed a significant ($P < 0.05$) decrease in arteriole diameter as concentrations of norepinephrine were increased and significant increases in diameter when concentrations of acetylcholine and adenosine were increased. In the young, the dose response vessel diameter significantly increased as the dose of acetylcholine was increased. However, the dose response vessel diameter did not significantly increase as the dose of adenosine was increased in either the aged or the young. The myogenic response was seen to a greater degree in the young as opposed to the aged. The passive curve showed a significant decrease in diameter as pressure was reduced in aged and young rats. The wall thickness data showed no significant changes as a function of age. These findings suggest that vascular smooth muscle does not change with age. Additionally, there is no significant interaction between wall thickness and vessel diameter. The myogenic response, contractile mechanism, and the ability to release nitric oxide diminish with age. Norepinephrine could be used as an effective treatment for severe orthostatic hypotension.

The validation of residual volumes for aspiration risk in clinically ill patients. JAMES A. STEFATER, duPont Manual High School, 120 W. Lee St., Louisville, KY 40208.

There are many indicators that correlate with development of pneumonia in ICU patients. However, one of the most popular risk indicators, high residual volumes, has no research to validate its legitimacy. This study looks at the validity of residual volumes as a marker of increased or decreased risk of regurgitation or aspiration. Patients were randomly divided into two groups: feeds in controls were not stopped when residual volumes were less than 400 cc, while in study patients; feeds were stopped at 200 cc to reduce the likelihood of aspiration or regurgitation. It is thought that the group with a higher residual volume cut-off will be more likely to develop positive aspiration

or regurgitation. Feeding bags for both groups were injected with detectable calorimetric microspheres and inert blue food coloring. Secretions were taken from the patients' oropharynx and trachea every 4 hours for 3 days. These secretions were evaluated for visual presence of blue food coloring and the quantity of calorimetric microspheres present in each secretion. Residual volumes of less than 200 cc failed to correlate with aspiration or regurgitation. Study results conclude that holding feeds for designated residual volumes may impede rather than facilitate external feeding. Blue food coloring, after having no positive identification in all 144 samples, has been designated an ineffective marker due to its incredible insensitivity. These conclusions are extremely important pieces of information because it is the common practice of most hospitals to cut feeds at residual volumes between 75 and 150 cc.

An alternative color for lights that need to be seen at low intensities. SHANA STODDARD, Central High School Magnet Career Academy, 1130 W. Chestnut St., Louisville, KY 40202.

The minimum intensity of light detectable by the human eye was studied for different colors of light. The hypothesis is that there is a difference in the minimum intensity of light that is detectable by the human eye based on differences in wavelengths. Colors with longer wavelengths, like red, will be seen at lower intensities than colors with shorter wavelengths, such as blue. Seventy-five male and female volunteers aged 33 $\pm$ 19 years (range 10 to 85 years) were enrolled and completed the protocol. Subjects were stratified into five groups of 15 individuals on the basis of age: 10 to 15 years (Group 1), 16 to 25 years (Group 2), 26 to 35 years (Group 3), 36 to 50 years (Group 4) and $\geq$50 years (Group 5). The minimally perceptible intensity of red and blue light was determined using a light-intensity-unit constructed from my personal design. If the individual wore corrective glasses ($n = 32$), they were tested with their glasses on and off for both colors. For the entire group ($n = 75$), minimal intensity of light perceptible was lower for red (0.07 $\pm$ 0.09 lux) than for blue (0.09 $\pm$ 0.02 lux, $P = 0.024$) light. The minimally perceptible light intensity for red light was higher for Group 5 (0.12 $\pm$ 0.15 lux) than Groups 1 (0.05 $\pm$ 0.03 lux, $P = 0.025$), 2 (0.04 $\pm$ 0.03 lux, $P = 0.01$) and 4 (0.06 $\pm$ 0.05 lux, $P = 0.05$), but did not differ from that of Group 3. However, the minimally perceptible light intensity for blue light did not differ between groups. The lowest intensity of perceptible light was lower for red versus blue light in Groups 1, 2 and 4, but did not differ in Groups 3 or 5. These data did support the hypothesis that red light is seen at lower intensities than blue light. The potential practical importance of my project could relate to use of specific colors of light that are more readily detected in emergency vehicles such as ambulances, fire trucks, and police cars.

Improved pulmonary function by hypoxic preconditioning involves upregulation of endothelial nitric oxide synthase (eNOS) and monocarboxylate transporter (MCT1). EFFIE WANG, duPont Manual High School, 120 W. Lee St., Louisville, KY 40208.

To uncover mechanisms underlying hypoxic preconditioning-mediated protection in the lung, tissue samples were collected from mice exposed to: 1) 21% oxygen; 2) 21% oxygen for 2-h after preconditioning (6 cycles of 10-min 6.5%/10-min 21% oxygen); 3) 5.7% oxygen for 6-h; and 4) 5.7% oxygen for 6-h following preconditioning and 2-h at 21% oxygen. Water content and lactate/glucose concentrations were measured. Also, total cellular protein and RNA were extracted for analysis of gene expression using Western and Northern blot analyses, respectively. Hypoxic preconditioning significantly reduced pulmonary edema caused by severe hypoxia (0.491 $\pm$ 0.111 vs. 0.894 $\pm$ 0.113 mg/mg dry tissue, $P < 0.025$; $n = 9$). This protection was associated with increased expression of eNOS protein in the lung (2.91 $\pm$ 0.13 vs. 1.00 arbitrary units, $P < 0.005$; $n = 6$). Further, hypoxia decreased (9.93 $\pm$ 6.09 vs. 33.94 $\pm$ 8.35 nmol/mg protein, $P < 0.025$; $n = 6$), whereas hypoxic preconditioning increased (91.78 $\pm$ 29.76 vs. 33.94 $\pm$ 8.35 nmol/mg protein, $P < 0.05$; $n = 6$) lactate concentration in the lung. The hypoxic preconditioning-induced increase in lactate concentration was associated with an upregulation of MCT1 protein in the lung (3.40 $\pm$ 0.29 vs. 1.00 arbitrary units, $P < 0.005$; $n = 6$). It was concluded that hypoxic preconditioning reduced the formation of pulmonary edema, hence improving survival during severe acute hypoxia. This protection involved upregulation of the *eNOS* gene. It was also concluded that lactate appeared to be the preferred source of fuel for the lung during severe acute hypoxia. Hypoxic preconditioning improved energy supply and cell integrity of the lung by stocking up lactate in lung cells through upregulation of the *MCT1* gene. The latter also contributed to the reduced formation of pulmonary edema following hypoxic preconditioning.

BOTANY

Thermotolerance acquisition by raddish seedlings, *Raphanus sativus*. ANDREA MASON, Notre Dame Academy, 1699 Hilton Drive, Covington, KY 41011-2796.

Heat shock treatment could aid agriculture by reducing the threat of early frosts and may also help develop hardier plants by a natural process. It has been shown that by heat shocking many different types of plants, including tomatoes, beans, and cucumbers for a minimal time a few degrees above their optimum temperature for growth, one can ultimately increase their tolerance for thermal and chilling stress. The purpose of my experiment was to investigate whether heat shocking raddish, *Raphanus sativus*, seedlings for 10 minutes at 40°C would increase their tolerance to chilling. I found that the heat shocked plants at room temperature grew a little more than the control group for the first three days of the experiment. Then the average growths leveled off, until ultimately the difference

between the control and heat shocked plants at room temperature was negligible. The difference between the chilled and heat shocked + chilled plants was also minimal. I concluded that the rubber bands that I used to hold the growing apparatus together might have put undue pressure on the roots, causing them to grow sporadically.

Thigmomorphism in dwarf corn. MONICA SUMME, Notre Dame Academy, 1699 Hilton Drive, Covington, KY 41011-2796.

The purpose of this experiment was to discover the effects of mechanostimulation on dwarf corn, *Zea mays*, plants. Plants were subjected to stimulation by means of hand stroking or wind. Both the root systems and stems were affected. Root systems of windblown plants were quite asymmetrical with about 80% more growth present on the side opposite the stimulus. Root systems of hand-stroked plants also showed marked asymmetry. The strength of the sessile leaves and the stems were increased by the stimulation as well, as detected using a computer-interfaced probe to monitor force as a pin punctured the stem in a transverse direction. The average force needed to puncture a control plant's sessile leaf was 0.332 N. The average needed for a plant that was stroked was 0.485 N, while that for a plant subjected to wind was 0.524 N. Phloroglucinol staining indicated the presence of lignin. It was found that lignin content was highest in plants grown in constant wind and lowest in control plants. Hand-stroked plants showed an intermediate amount. The research establishes the fact that mechanostimulation affects this particular species of plant rather drastically. The plants respond by developing stronger stems and adjusting the root systems to compensate for the stimulus.

CHEMISTRY

The synthesis of ion selective silver sulfide electrodes. JAY ANDERSON, duPont Manual High School, 120 W. Lee St., Louisville, KY 40208.

In the field of analytical chemistry, many different techniques are available to analyze soil samples. One of the more often used techniques is with ion selective electrodes (ISE). Current ISE electrodes are mostly manufactured by commercial companies and are not built to suit the individual needs of scientists. Ideally a hand held or backpack size model would be built to speed up analysis and allow data to be collected on site. For this to be constructed, the main part of the detection unit, the ISE, has to be customized to fit the needs of the developer. Using cyclic voltammetry, a varying voltage of 0 to +1.5 volts was applied to a silver electrode submerged in a 250 mL solution of NaOH at 0.1 mol with 40 mL of laboratory grade NaS_2. This added a black coating around the electrode believed to be composed of silver sulfide ions, which would allow it to detect sulfides. A potentiometric experiment was then undertaken to determine if the electrode reacted when a sample of sulfide was present. The coated part of the electrode was placed into a NaOH solution of 0.1 mol with a reference electrode on a stirrer plate. The electrodes were connected to a digital multimeter and measured additions of a diluted 0.01 mol solution of NaS_2. The fragility, lifetime, and durability of the electrodes were low and the thickness of the coating varied, eliminating the feasibility of producing such electrodes.

COMPUTER SCIENCE & MATHEMATICS

Three-dimensional applications of Pick's Theorem. ADAM R. CHAWANSKY, duPont Manual High School, 120 W. Lee St., Louisville, KY 40208.

George Alexander Pick published the theorem bearing his name in 1899. Pick's theorem states that the area of a simple lattice polygon equals $B(P)/2 + I(P) - 1$. This project sought to determine if a similar formula could be created for calculating volume for three-dimensional solids. For the purpose of this experiment, slightly different definitions of the variables B (boundary) and I (interior) were considered. Since three dimensions were being manipulated, it was believed another variable may have been necessary. The inclusion of an S (side) variable was used for the lattice points on the sides of a solid. The variables were also examined when B equaled all of the points on the edges and faces of the solid; I continued to equal all of the points inside the cube. However, this method quickly led to data devoid of a meaning. After defining the variables, different shapes were imaged using a pseudo-grid formed by K'Nex, and the variables and volume were computed using appropriate formulas. To simply things, one or two variables were often used as controls while the remaining variables were examined for patterns. Patterns were found, but they were not coherent enough to form a general formula. Due to research conducted prior to the experiment, it is believed a general formula may be constructed with higher level mathematics than were available. Such a formula might allow simplified computation of volume in three or more dimensions.

Digital electroencephalograph recording and analysis: software for researchers. MARK GRUENTHAL, duPont Manual High School, 120 W. Lee St., Louisville, KY 40208.

Epilepsy is a common malady that disables thousands of people. Rats are the most common animals used by researchers to study epilepsy and its potential treatments. During an epileptic seizure, the currents emanating from brain cells (neurons) become synchronized and grow in strength and frequency. A device called an electroencephalograph (EEG) is used to record and analyze these electrical currents and seizures. Traditional EEGs use analog data that is displayed with ink pens on scrolling paper. Researchers rely on these paper traces to do their analyses; having to resort to hand measurements in order to detect the duration, frequency and severity of the seizures. Through a process called analog to digital conversion, analog data can be converted into digital data that can be stored by computer. However, these technologies have only been utilized for human EEGs and at great expense. The purpose of the current project was to create

a cost-efficient method for collecting digital EEG data on rats. Such software does not exist to date. Software was developed to input, save, and replay EEG data with a computer. Seizure duration can be automatically determined. After development of the software, testing was performed on rats to determine the effectiveness of the procedure. The conversion software produced accurate, reproducible results. This software may be a useful tool for the estimated 300 laboratories in the United States alone that study epilepsy with rats.

Golden mean and nature. JUSTIN LEWIS, Science Department, duPont Manual High School, 120 W. Lee St., Louisville, KY 40208.

This research project deals with the Golden mean and how it relates to nature. The Golden mean is a number based on the Fibonacci Sequence (1, 1, 2, 3, 5, 8, 13, 21 . . .), which adds the last two numbers to get the next number in the pattern. This pattern was seen to occur several times in nature. But does it occur regularly? The hypothesis was that the plants studied would show the Golden mean and the Fibonacci sequence. The methodology involved examining 75 specimens of each of three plants (pine cones, cauliflower, and broccoli) and counting their spirals. Effort was made to get plants as close in size as possible. If one observes from the top of a pinecone or cauliflower, one will notice spirals that go in both directions (clockwise and counter-clockwise). This study found that the number of spirals in cauliflower and pine cones are always Fibonacci numbers, as well as Golden mean proportions. However, it was found that broccoli did not have any spirals and, thus, broccoli showed no pattern in this study. Therefore, it is concluded that the Golden mean does occur regularly in nature; but, not in everything.

Development of a computer database using Microsoft software. JIE MA, duPont Manual High School, 120 W. Lee St., Louisville, KY 40208.

This project focused on the formation of a computer database using Microsoft Access and relevant programming languages such as Visual Basic (VB). The aim was to create a database with essential information in math, science, and computers to aid high school students in their education. Microsoft Access was chosen because of its aptness in size (for small business and personal use) and function (simple to use yet very powerful). The programmer first entered data into individual tables (here data is sorted), then created complementary forms and relevant queries were made. Tables and forms were then implemented by VB code in a user-friendly environment (a form) with interactive buttons and icons for user-convenience. The finished database featured substantial data of three subjects (general math, science, and C++ programming aid) with sub-menus beneath each icon. VB code was also used to program the buttons and other necessary links in the forms. The template for each form display is well-structured. Although no formal testing was done, several student testers responded receptively to using the database in aiding their school work.

E-Commerce security. SOWMYA SRINIVASAN, duPont Manual High School, 120 W. Lee St., Louisville, KY 40208.

After observing the recent rise in the usage of the E-Commerce market, it was seen that security has become a hot topic. In general, the public does not have fears about making transactions at stores or via telephone, but fears do arise while making transactions on-line. There is general anxiety about giving out credit card numbers through the Internet. This study focused on the different methods of securing servers to protect them from hackers and viruses, and to ensure that card numbers are not given out. These security methods include encryption, secure socket layer (SSL), secure electronic transaction (SET), firewalls, and smart czards. This research was then compiled and analyzed to suggest the best security method for the near future.

Stock market vertigo and irrational reactions to index milestones. LAWRENCE M. WATKINS, Louisville Male High School, 4409 Preston Highway, Louisville, KY 40213.

We conducted an investigation into market activity during periods in which the Dow Jones Industrial Average is in close proximity to major market milestones. In contrast to predictions of asset pricing theory, we find that investors exhibit peculiar trading patterns, even among stocks that have very little correlation with those included in the 30-stock index. More specifically, we find that trading volume declines significantly as the Dow approaches each milestone and it increases significantly as the milestone is surpassed. In addition, return volatility tends to increase during these periods, and the standard volume/volatility relationships documented in the literature change direction in the presence of major milestones. Finally, for the Dow itself, there are significantly fewer price reversals when the index is in close proximity of a milestone. These results are found to exist among all three exchanges and among most size deciles within exchanges, even for those portfolios with assets that are not included in the calculating of the Dow. These results have compelling implications for option pricing, as well as the general debate on market efficiency. The data we used was collected by the Center for Research in Securities Prices Database, using daily stock returns from 1972 through 1999. This period was chosen because all 1,000 point market milestones were surpassed after this date.

The validity of using firewalls as intrusion detectors in computer systems. JUSTIN WIBLE, Seneca High School, 3510 Goldsmith Lane, Louisville, KY 40220.

A study was performed using the most up to date firewall to determine its validity as an intrusion detector in computer systems. The experiment was designed to show the overall accuracy of the firewall, as well as to determine

if there are ways to break through the wall or go around it. I expected to get through the perimeter code fairly quickly, but would be caught and ejected quickly once into the deeper parameter. I expected the firewall to catch my intrusions approximately 85-95% of the time. I found that the Sonicwall is approximately 97% effective at catching intrusion, and when used in a comprehensive network, it provides adequate protection.

EARTH & SPACE SCIENCE

Earthworms as natural decomposers. JOHN MEIGOONI, Morton Middle, 1225 Tates Creek Rd., Lexington, KY 40502.

In this project the effect of earthworms on the germination and growth of grass seeds was measured. Measurements were performed by comparison of grass heights with different numbers of earthworms, to grass height without earthworms. Four planting pots were labeled as control (no worms), 3 worms, 6 worms, and 10 worms. These pots were filled with topsoil up to 2 inches from the top. Then earthworms were added to each pot according to the labels on the pot. One-quarter cup of grass seeds was added to each pot and another quarter cup of topsoil was added on the top of the seeds. Each pot was given one cup of water. All pots were placed in the basement in front of a window and were watered every other day. Growth of grass seeds and other observations were recorded after germination. The growth of the grass was measured from the top of the soil in the pots to the average tip of the grass. After 22 days, the height of the grass was found to be 15 cm, 16 cm, 18 cm, and 20 cm in the pots with control, 3 worms, 6 worms, and 10 worms, respectively. The results of this project had shown that grass heights were 33%, 20%, and 6.7% taller in the pots with 10 worms, 6 worms, and 3 worms, respectively. Also, more seeds germinated in the pots with the larger number of worms. This experiment was repeated again under the same conditions and ended with the same results. Therefore, the earthworms did act as natural decomposers.

Stratification in granular materials. ALLISION MORRIS, Notre Dame Academy, 1699 Hilton Drive, Covington, KY 41011-2796.

When an originally homogeneous mixture is poured into a quasi-two-dimensional cell, spontaneous stratification occurs. This experiment involved a 50/50 volume mixture of sand particles ranging from 841 to 1190 micrometers and sugar particles ranging from 10 to 170 micrometers. Both types of grains had an average aspect ratio of 1.4. When these gains were poured slowly into a vertical Hele-Shaw cell, regions of stratification and segregation formed. The dark sand stripes were somewhat broader than the light sugar stripes. The purpose of my experiment was to test the effects on the stratification when the cell was tilted away form vertical. As the cell was angled further from vertical, the stratification became less apparent and three-dimensional segregation occurred. There was an increasing concentration of sand on the top of the cell and sugar of the bottom of the cell. This probably occurred because when the cell was tilted, the speeds of the rolling particles were reduced. This allowed more time for the small grains to fall to the bottom of the cell.

Investigating variables in the universal soil loss equation. CHRIS REZVANIAN, duPont Manual High School, 120 W. Lee St., Louisville, KY 40208.

Many agriculturists use the universal soil loss equation (USLE) to predict average annual soil loss. This experiment was conducted to investigate and revise the USLE to account for soil moisture and seasonal rainfall variations. A revised equation was created to evaluate circumstances of natural weathering from summer through fall (June 20, 2000–December 22, 2000). A sine regression that fits the plotted data of average monthly rainfall in Louisville was successfully found using a TI-83 calculator. Using this sine regression, the rainfall factor (R factor) in the USLE as well as the soil erodibility factor (K factor) were manipulated to create a revised soil loss prediction equation that can be applied to short term erosion prediction. The rainfall in the summer and fall of 2000 were very similar to the average rainfall. This increased data significance in my project. The revised USLE was compared to the standard USLE and found that the revised USLE was much less than half of the standard predicted soil loss for Louisville, KY; therefore wholly supporting my hypothesis. After the 26 weeks of natural weathering on the ditch, it was found that approximately 490 pounds of soil eroded from the surface of the ditch. The revised USLE predicted that the ditch would displace 483.17 pounds of soil over the 26-week period. These results are very significant and fall under the 0.05 probability level using a T-test.

ENGINEERING

Effects of abscisic acid and gibberellic acid on tensile and compressive strength of bamboo. JULIE WOLFE, Notre Dame Academy, 1699 Hilton Drive, Covington, KY 41011-2796.

Bamboo, *Phyllostachys aureosulcata,* has many practical uses. It is used as a building material in developing countries, but displays some structural weaknesses. The purpose of my research was to see if adding a plant growth hormone to the bamboo's water supply would influence its strength under compression and tension. Abscisic acid (ABA) and gibberellic acid (GA) solutions (10^{-5} M) were used to water bamboo plants in an attempt to change the physical characteristics of the bamboo. Once new bamboo shoots had appeared after application of the chemicals, they were tested for their strength under compression and stretching. An apparatus was designed to record both force and position data while stems containing three nodes were compressed longitudinally and stretched transversely. Slopes of the graph of distance vs. force during initial deformation were calculated for each hormone and the control. The ABA stalks compressed an average 0.99 mm/N of applied force, while the GA compressed an average

of 10.2 mm/N. The ABA was substantially stronger than the control and the GA. When GA plants failed it was usually from buckling and the ABA from longitudinal splitting. When their tips were pulled upward, the ABA plants rose an average of 193 mm per N and the GA 184 mm/N. Both of these deflected more readily than the control.

ENVIRONMENTAL SCIENCE

Water quality assessment of St. Asaph's Creek, Stanford, KY. MICHAEL J. BAILEY, Lincoln County High School, Stanford, KY 40484.

Six sites along St. Asaph's Creek were monitored monthly from November 2000 to January 2001 to determine the water quality of the creek. Temperature, pH, dissolved oxygen, total hardness, nitrates, phosphates, and coliform concentrations were recorded for each site. When water quality results were compared to the criteria given by Project Clean Stream, the creek, which is of major historical importance, was ecologically healthy, though undrinkable. The creek can support fishing. To monitor future health of this creek a website was developed for students and teachers to use in a high school science curriculum.

Structural characteristics of hair as determiners of oil adsorbing ability. MARGUERITE BLIGNAUT, Notre Dame Academy, 1699 Hilton Drive, Covington, KY 41011-2796.

The purpose of this experiment was to discover which external characteristics of hair affect its ability to adsorb oil. NASA has done preliminary tests on the feasibility of using hair to clean up oil spills. This experiment was done using seven samples, each of which contained six switches of a different type hair. A mixture of oil and water was poured over the switches and the amount of motor oil adsorbed per gram of hair was determined. These averages ranged from 0.154 to 1.32 g oil/g hair. Pit depth and spacing on the hair surface were measured using *NIH Image* software. The average diameter of each hair type was calculated using laser diffraction. It was found that diameter, color, and waviness did not affect the hair's ability to adsorb oil. Pit depth and pit spacing did affect oil adsorption. The average pit depth ranged from 4.7 to 11.4 DN units and the average pit spacing from 2.5 to 3.7 μm. The greater the pit depths were, the more oil could be adsorbed. The greater the pit spacing, the fewer the pits available for adsorption. A possible predictive indicator, "Surface Factor," was defined as the quotient of the pit depth and the pit spacing. The "Surface Factor" correlated well but not perfectly with the hairs' ability to adsorb oil. Surface area has not yet been taken into consideration because of lack of time. At this time it is known that pit depth and pit spacing markedly affects a hair's ability to adsorb oil.

Substrate impairment vs. water quality in macroinvertebrate communities of Beargrass Creek. AMANDA LEISTER, Seneca High School, 3510 Goldsmith Lane, Louisville, KY 40220.

The purpose of this project was to see how substrate and water quality in creeks affects macroinvertebrate organisms living there. By surveying aquatic invertebrates in Beargrass Creek it will be possible to assess the quality of the creek. Observations on the stream site and the watershed will allow identification of environmentally damaging practices or conditions. This was done with the use of inexpensive, simple equipment to make my biological assessment of Beargrass Creek. The placement of Hester-Dendy devices at three different sites in Beargrass Creek was to ensure accurate results along with determining if organism diversity was low due to lack of substrate or poor water quality. The Hester-Dendy device is a type of artificial substrate that is submerged under water for macroinvertebrate animals to adhere to. Along with the Hester-Dendy devices, substrate and water quality were tested. This was to give quantitative data in the case of nothing attaching to the Hester-Dendy devices. This was also done to show why all the organisms that attach to the sampler were from the taxa three category. (Organisms that are pollution tolerant and can be in any quality water.) If organisms grow on the Hester-Dendy devices and there are no organisms in the substrate when it is tested, then the water quality of Beargrass Creek is fair enough for organisms to live in, but the substrate is poor. If the organisms on the Hester-Dendy devices are from the taxa three category of macroinvertebrates, then water quality is also poor. Depending on the results the substrate could very well be poor too. This means the creek needs, not only to fix the water quality, but also to have what man has done to the creek taken out (channelization) to fix the substrate impairment. If there are organisms on the substrate but not on the Hester-Dendy devices, then the water quality is good along with the substrate. This means nothing needs to be done to Beargrass Creek. The water quality at each site has remained moderately constant and is overall fair quality, and the substrate quality tested to be fairly poor. There were abundant macroinveretebrates attached to all six Hester-Dendy devices. Considering the water quality was fair, according to the Kentucky Water Watch Network, this shows the substrate is what is poor in Beargrass Creek. Poor substrate is the cause of a scarce amount of macroinvertebrates. The Beargrass Creek Preserve is currently utilizing approximately 1.8 million dollars to improve water quality. As a result, it would be expected that the diversity of macroinvertebrates would increase. I hypothesize that substrate has more influence on macroinvertebrate diversity than the current water quality in Beargrass Creek.

Tested water samples of Big Pine Key, FL. KELLY THAYER, Taylor County High School, 300 Ingram Avenue, Campbellsville, KY 42718.

The research was conducted to test pollutant levels in Big Pine Key, FL, and how they affect coastal ecology. Salt water samples were taken from three sites in Big Pine

Key, FL. These sites were a mangrove shoreline (Site #1), Looe Key Reefs (Site #2), and the boating dock of the Newfound Harbor Marine Institute (Site #3). These samples were tested for levels of iron, nitrate, dissolved oxygen, and pH. Five milliliters of salt water were collected from each site. Samples were treated with two chemical reagents to test iron content. Results were then compared to an Iron Octet Comparator. In all cases, iron was found to be in the range of 0 to 0.5 ppm. The pH levels were then tested. Again, 5 mL of water from each site was obtained. Indicator solution was added and the sample was then inverted. Site #1 had a pH of 7.5, Site #2 was 8.3, and Site #3 had a level of 6.3. Dissolved oxygen was also tested. Samples were prepared and several chemical solutions were added to the water samples. The three sites produced levels found to be 7 ppm. Nitrate (NO_3^-) levels were tested with fixed salt water samples. Nitrate reagents were then added to each sample and the samples were inverted. After completing the test, the Nitrate-N Comparator showed levels at the three sites that ranged from 0 to 0.25 ppm.

MICROBIOLOGY

The magnitudes of bacteria inhibition caused by divergent mouthwashes. ANNE CHMILEWSKI, duPont Manual High School, 120 W. Lee St., Louisville, KY 40208.

Mouthwash is one of the most convenient ways to cleanse the mouth of bacteria. However, the variety of mouthwashes is phenomenal and a myriad of ingredients is available. This experiment was a quest to find the mouthwashes that will inhibit the growth of bacteria commonly found in the mouth. Antibiotics are often tested on a plate of bacteria before being given to a patient to insure that the bacteria will respond to the antibiotic. This is known as sensitivity testing. This experiment slightly modified that idea and tested mouthwashes, instead of antibiotics, against the bacteria *Staphylococcus epidermidis* and *Viridans streptococci.* Seven mouthwashes were tested with herbal, enzymatic, and alcohol ingredients. The results show that hydrogen peroxide mouthwash does a tremendous job against *S. epidermidis* and *Viridans streptococci.* Scope Original Mint and Herbal Mouth and Gum mouthwashes partially inhibited the bacteria. Tea Tree Oil provided inhibition for *Viridans streptococci* only. The other three mouthwashes did not exhibit inhibition. The experiment is limited in its conclusions. It may be that the test used allows alcohol to evaporate before it completes its job. The experiment also only tested two bacteria species, while the variety of bacteria in the mouth is innumerable. Further research would facilitate more conclusive and useful results.

Enhancement of the radiation effect on DU-145 cancer cells using curcumin. DAVID MEIGOONI, Paul Laurence Dunbar High School, 1600 Man O'War Blvd., Lexington, KY 40513.

The purpose of this project was to investigate enhancement of the radiation effect to prostrate cancer cells using curcumin. This may help to reduce the amount of radiation needed to treat prostate cancer patients. In this project, enhancement of radiation effect on PC-3 and DU-145 prostate cancer cells was determined by comparing the survival fraction of cells receiving radiation alone to that of cells irradiated after addition of 2 μM or 4 μM curcumin. PC-3 and DU-145 cells were plated in 25 cm^3 flasks and the surviving colonies were stained and manually counted 14 days after the treatments, by utilizing colony-forming assay. The ratio of the number of colonies counted to the number of cells plated multiplied by the plating efficiency was used to obtain the survival fraction. A linear-quadratic model was used to analyze the survival fractions for each treatment. The results of this investigation have shown that the survival fraction of PC-3 was 0.435 for 2 Gy of radiation alone. The survival fraction was decreased to 0.224 and 0.027 by adding 2 μM or 4 μM, respectively, of curcumin. For DU-145 the survival fraction was 0.682 for 2 Gy of radiation alone, and was decreased to 0.565 and 0.434 by adding 2 μM or 4 μM, respectively, of curcumin. The final results indicated that the radiation effect on PC-3 was enhanced by a factor of 1.45 or 8.7 when 2 μM or 4 μM, respectively, of curcumin was added prior to irradiation. However, the effect of radiation on the DU-145 cell line was enhanced by a factor of 1.04 or 1.14 when 2 μM or 4 μM, respectively, of curcumin was added prior to the irradiation. Based upon these results, curcumin sensitizes prostate cancer cells to radiation.

Response of *Physarum* to various sugars. ANGY MOUNIR, Notre Dame Academy, 1699 Hilton Drive, Covington, KY 41011-2796.

Plasmodial slime molds are basically enormous single cells with thousands of nuclei. During the active stage of their life cycle, slime molds exist as motile plasmodia that are capable of "flowing" toward nutrients. They feed on a variety of organic material, decaying organic matter, bacteria, and protozoa. The purpose of this experiment was to test the ability of the slime mold, *Physarum polycephalum,* to distinguish among different types of sugar. Agar cubes, containing various sugars (sucrose, lactose, glucose, and levulose), were placed on one side of a sterile petri dish and a plain agar cube was placed on the other. The slime mold was streaked on non-nutrient agar in the center and grew toward its preferred nutrient source. It was found that *Physarum* consistently moved toward glucose and sucrose. When presented with levulose on one side and glucose on the other, the *Physarum* migrated towards glucose. No attraction for lactose was evident. *Physarum* seems to be able to distinguish between different types of sugars.

PHYSICS

Effect of low frequency vibrations on strength of magnetic fields on flexible spinning discs. OLUMAKINDE ADEAGBO, duPont Manual High School, 120 W. Lee St., Louisville, KY 40208.

Magnetic fields on flexible rotating discs may be weakened by vibration. Since magnetic discs are prevalent in sound recording and data storage, it is important that the information is not lost. Floppy discs are a good example of such discs. As a current passes through the head of the drive, a magnetic field is created around it and the medium. In the same way, reversing the direction of current reverses the polarity of the field. When the magnetic field is too weak, the head cannot "read" the fields. The amplitude and frequency of vibration will have different effects on magnetic fields. The amplitude should create a very small change in the magnetic field, but the frequency should have a far greater effect. This hypothesis was tested with an apparatus that oscillated a floppy disc drive, spinning a disc at variable spin rates at frequencies ranging from 0 Hz to 100 Hz and amplitudes from 0.01 to 0.05 inches. The number of sectors on the disc was measured before and after the test to see the error rate on the disc. The hypothesis was supported by the data collected. As the frequency of the vibration approached 100 Hz, the error rate began to increase around 60 Hz. The error rate reached 0.7% at amplitudes of 0.02 and 0.03 inches. At the higher amplitudes of 0.04 and 0.05 inches, the error rate stayed below 0.1%.

In situ measurement of rupture forces between biotin and streptavidin with atomic force microscopy. VINITA ALEXANDER, duPont Manual High School, 120 W. Lee St., Louisville, KY 40208.

Nature can distinguish between molecules via recognition of multiple noncovalent bonds and their unique and inherent intermolecular forces. Based on these specific forces, it is possible to determine cellular behavior and immunological response. The atomic force microscope has the ability to map the topography of nanoscale matter as well as to measure intermolecular forces that govern nature. In the future it will function as a biosensor and a means to detect nerve gases. But first, the forces that will govern each molecular pair must be irrefutably established. The streptavidin-biotin (S-B) complex is a highly adhesive ligand-receptor pair whose forces have yet to be precisely measured with research-endorsed force measurements ranging from 200–393 piconewtons. In this study of the S-B complex, polyethylenimine(PEI)-polyethyleneglycol (PEG) films were formed atop silicon cantilevers. The liquid cell and PEG esters were used as barriers against the inclusion of nonspecific interactions in the detection of specific forces. In each run, a precoated streptavidin slide was employed as the substrate, and M-PEG, a blocker of endogenous activity expected to experience no force, was a control. Force findings between the S-B complex were expectedly low (220 piconewtons), attributed to the PEG and liquid cell, while those detected in the case of M-PEG were unexpectedly high (330 piconewtons).

ZOOLOGY

Effect of red dye #40 and methyl orange on the pulsation rate of a worm, *Lumbriculus variegatus*. LISA SOPER, Notre Dame Academy, 1699 Hilton Drive, Covington, KY 41011-2796.

The purpose of this experiment was to determine the effects of dyes on the pulse rate of a worm, *Lumbriculus variegatus*. A chamber was constructed of parafilm and a microscope slide into which a worm was placed and videotaped using a flexcam. The worm was then exposed to red dye #40 or methyl orange (0.01%) and videotaped. Using Videopoint Capture software, pulsation duration was determined and beats/min were calculated. Red dye #40 significantly increased ($P < 0.05$) average pulsation rate in two out of three trials. The muscular wave going through the dorsal vessel appeared visually less orderly and much weaker than in the control. Methyl orange had the opposite effect with three out of four trials showing a decreased pulsation rate. No visual changes were apparent.

Ecological studies of tardigrades in Cherokee Park, Louisville, KY. ZOE ZHANG, duPont Manual High School, 120 W. Lee St., Louisville, KY 40208.

Tardigrades are microscopic invertebrates of the phylum Tardigrada. Very little is known about tardigrades; only 800 species have been identified. Five samples of stream-side, ground, and tree moss were collected during the first day of the month from September to December 2000. Tardigrades were collected and classified. The number of tardigrades in each habitat was approximately the same as was the number collected each month. This did not support my hypothesis that the stream-side moss would have the largest number of tardigrades. Though the number of tardigrades remained the same throughout the period of observation, the development changed greatly. In the September and October samples, the majority of tardigrades found were adults. In November and December, the majority of tardigrades found were eggs or larvae. This supports my hypothesis that, as winter progressed, the tardigrades would lay their eggs and the majority of the adults would then die. There were 14 individuals of *Macrobiotus hufelandi*, two *Echiniscus gladiator*, two *Pseudobiotus* spp., and two *Thulinia* spp.

J. Ky. Acad. Sci. 63(1):87–92. 2002.

CONSTITUTION OF THE KENTUCKY ACADEMY OF SCIENCE

(Adopted 8 May 1914. Revised November 1951, 1970, 1979, 1987, 2000)

ARTICLE I

NAME

Section 1. Name. This organization shall be known as the Kentucky Academy of Science.

Section 2. Objectives. The objectives of the Academy shall be to encourage scientific research, to promote the diffusion of scientific knowledge, and to unify the scientific interests of the Commonwealth of Kentucky.

ARTICLE II

MEMBERSHIP

Section 1. Classes of Membership. The membership of the Academy shall consist of Regular, Life, Student, Honorary, and Emeritus Members, and Corporate and Institutional Affiliates.

Section 2. Regular Members. Regular Members shall be individuals who are interested in science and the objectives of the Academy. Each Regular Member shall pay annual dues as prescribed in the Bylaws.

Section 3. Life Members. Life Members shall be members who have paid at one time suitable sums as prescribed in the Bylaws, or have paid at least that sum as an endowment and are therefore relieved from further payment of dues.

Section 4. Student Members. Student Members shall be full-time undergraduate, or part-time or full-time graduate students. Each Student Member shall pay annual dues as prescribed in the Bylaws. Student Members shall have all the rights and privileges of Regular Members but may not hold office. No individual shall be allowed to be a Student Member for more than six years.

Section 5. Honorary Members. Honorary Members shall be persons who have acquired national or international renown in science. They shall enjoy all the privileges of active membership except holding office and shall be free from all dues. The number of Honorary Members shall not exceed twenty at any time.

Section 6. Emeritus members shall be members who have retired from active professional service and who petition the Executive Committee for a change in classification. They shall enjoy all the privileges of active membership except holding office and shall be free from all dues. They shall receive all mailings except the *Journal*.

Section 7. Corporate and Institutional Affiliates. Corporate Affiliates and Institutional Affiliates shall be businesses, industrial or academic institutions, departments of such corporations or institutions, or individuals who through support have indicated their endorsement and espousal of the aims and purposes of the Academy. Annual dues shall be paid as prescribed in the Bylaws.

Section 8. Election to Membership. For election to any class of membership, the individual should apply for membership and must have paid the first year's dues.

ARTICLE III

OFFICERS

Section 1. Elected Officers. The elected officers of the Academy shall consist of President, President-elect, Vice President, Past President, Secretary, and Treasurer.

Section 2. Appointed Officers. Other officers shall be appointed by the President and approved by the Governing Board. These shall serve continually at the discretion of the President and Governing Board. They shall consist of the Executive Secretary of the Academy, the Editor of the *Journal*, the Program Coordinator, the Director of the Kentucky Junior Academy of Science (KJAS), the Editor of the Newsletter, the Editor of the KAS Web Page, the Representative to the American Association for the Advancement of Science (AAAS), and Representative to the National Association of Academies of Science (NAAS).

Section 3. Election of Officers. The Vice President shall be elected annually by mail ballot and, after having served one year, shall succeed the office of President-elect. The Secretary and Treasurer shall be elected for three-year terms, the election to take place by mail ballot in autumn of the year prior to taking office.

Section 4. Term of Office. The elected officers shall take office on January 1 following the fall meeting and shall hold office until their successors have taken office. Any vacancy of an office shall be filled by appointment by the President subject to approval by the Governing Board.

Section 5. Presidential Succession. The President-elect shall succeed the retiring President and the Vice President shall become President-elect. If the President-elect is unable to assume office, the Vice President shall succeed to the presidency and both a President-elect and a Vice President shall be elected at the fall meeting.

ARTICLE IV

GOVERNING BOARD

Section 1. The Governing Board shall have the responsibility for the overall direction of the affairs of the Academy. It shall conduct the business of the Academy, subject to decisions on policy by the membership through mail ballots or at a meeting of the full Academy. The Board shall consist of the following: President, President-elect, Vice President, Past President, Secretary, Treasurer, Ex-

ecutive Secretary, Editor of the *Journal of the Kentucky Academy of Science*, Editor of the Newsletter, Editor of the Web Page, Program Coordinator, Director of the Kentucky Junior Academy of Science, Representative to the NAAS and AAAS, and six representatives elected by the three divisions of the Academy, two from each division, and two at large representatives elected from the Academy. The newly elected Governing Board shall take office on January 1 following their election.

Section 2. The first meeting of the new Governing Board shall be held within three months after the adjournment of the fall meeting of the Academy, and quarterly thereafter.

Section 3. Executive Committee. The Executive Committee shall consist of the President, President-elect, Vice President, Past President, Secretary, Treasurer. The Executive Secretary and Editor of the *Journal* shall serve on the Executive Committee in an *ex officio* capacity. The President may ask other appointed officers to serve in an *ex officio* capacity as members of the Executive Committee subject to approval of the Governing Board. The Executive Committee shall execute and administer the affairs of the Academy during intervals between scheduled meetings of the Governing Board.

ARTICLE V

DUTIES OF OFFICERS

Section 1. President. The President shall discharge the usual duties of a presiding officer at all general meetings of the Academy, the Governing Board, and the Executive Committee. The President shall stay constantly informed on the affairs of the Academy and on its acts and those of its officers, and shall cause the provisions of the Constitution and Bylaws to be faithfully carried into effect, including making appointments described herein.

Section 2. President-elect. The President-elect shall assume the duties of the President in the event of the President's disability or absence from the general meetings of the Academy, the Governing Board, or the Executive Committee. The President-elect shall serve as Chair of the Program Committee.

Section 3. Vice President. The Vice President may assist the President and the President-elect in the discharge of their duties. In the event that both the President and the President-elect are unable to preside over a meeting of the Academy, the Governing Board, or the Executive Committee, the Vice President shall preside in their stead (.) Vice President shall also serve as Chair of the Awards Committee.

Section 4. Past President. The Past President shall serve as an advisor and consultant to the President in order to provide continuity in the development and implementation of long-term policies of the Academy. The (Past) President shall serve as Chair of the Planning Committee.

Section 5. Secretary. The Secretary shall keep the records of the proceedings of the Academy, the Governing Board, and the Executive Committee. The Secretary shall prepare such correspondence of KAS as requested by the Executive Committee.

Section 6. Treasurer. The Treasurer shall keep detailed records of all funds of the Academy and of the Kentucky Academy Foundation. He/she shall be familiar with the status and actions of the Athey Trust, through cooperation with the agent of KAS for coordination with the Trustee of said Trust. The Treasurer shall establish an operating account for the use of the Executive Secretary, and monitor the overall expenditures from that account. The Treasurer may deposit funds received by the Academy or Foundation into the appropriate accounts, and disburse payments for expenses of the Academy. The Treasurer shall make investments of Academy and Foundation funds as approved by the Finance Committee and reviewed by the Governing Board. The Treasurer shall keep a detailed account of receipts and disbursements, and shall secure an annual audit conducted by an external auditor. The Treasurer shall furnish a suitable corporate security bond, the premium thereof to be paid by the Academy.

Section 7. Executive Secretary. The Executive Secretary shall serve at the discretion of the President and Governing Board, and shall have such duties as directed by the President and Executive Committee. The Executive Secretary shall maintain a complete list of members of the Academy, including dues status of all members, and dates of their election to membership and separation from the Academy, to the extent possible. That Executive Secretary shall cooperate with the President in attending to the ordinary affairs of the Academy and shall have charge of registration at the fall meeting. The Executive Secretary shall serve as Chair of the Public Relations Committee. In the event that the Executive Secretary is not able to serve, the duties of that office shall fall back to the Executive Committee. The Executive Secretary shall furnish a suitable corporate security bond, the premium thereof to be paid by the Academy, and shall be subject to the same audit as the Treasurer.

Section 8. Editor. The Editor of the *Journal of the Kentucky Academy of Science* shall be appointed by the President, serve at the discretion of the President and Governing Board, and be assisted by an Associate Editor, also appointed by the President. The editor shall serve as Chair of the Publications Committee, and maintain a record of all page charges assessed and collected and all expenses associated with preparation and distribution of the *Journal*. The editor shall also maintain an updated list of referees for review of manuscripts submitted for publication, and establish standards of acceptance or rejection of manuscripts in accordance with publication policies submitted by the Publications Committee, reviewed and approved by the Executive Committee.

Section 9. Program Coordinator. The Program Coordi-

nator shall serve to coordinate efforts of the Governing Board and the Program Committee and Local Arrangements Committee in planning and conducting the annual fall meeting. He/she shall have responsibility and authority for scheduling of meeting events and for production of the annual meeting program. The Program Coordinator shall coordinate the Undergraduate Paper Competitions and shall serve as the principal liaison between the Governing Board and the Sections of the Academy.

Section 10. AAAS/NAAS Representative. The Representative to the American Association for the Advancement of Science and National Association of Academies of Science represents the Academy in AAAS matters, and shall keep the Academy informed on AAAS and NAAS transactions that may relate to the Academy interests. The President may appoint an alternate if the representative is prevented from serving for a period of time.

Section 11. Director of Kentucky Junior Academy of Science. The Director of the Junior Academy of Science is responsible for administration of all activities of the Junior Academy. The Director shall cooperate with the Junior Academy Steering Committee to develop and promote the Junior Academy as the principal science education outreach of the Academy. He/she shall plan and conduct the annual Spring Symposium of the Junior Academy and shall publicize this and other Junior Academy events. He/she shall periodically provide reports to the Governing Board on the activities of the Junior Academy.

Section 12. Newsletter Editor. The Newsletter Editor shall be responsible for the content, preparation, and mailing to the membership or transmittal to the Executive Secretary of the regular quarterly Newsletter of the Academy. Upon request of the President and/or the Executive Committee a special edition of the Newsletter may be prepared to meet a special communication need. Sole discretion of the content of the Newsletter rests with the editor subject to periodic review and approval by the Governing Board.

Section 13. Web Page Editor. The editor of the Academy web page shall maintain and regularly update the Academy site. He/she shall maintain current postings of all upcoming events of the Academy and Junior Academy and will develop and maintain the site as a principal source of information on the Academy. The editor shall provide and maintain downloadable forms for application for membership, meeting registration, and submission of abstracts of papers to be presented at the annual meeting. The editor shall maintain a list of current officers, governing board members and section officers of the Academy, together with the means for contacting those officers. The editor shall also provide such information of the Academy that he/she deems significantly in support of the Academy or its activities subject to review and approval by the Governing Board.

ARTICLE VI

DIVISIONS

Section 1. Designation of Divisions. For representation on various bodies of the Academy and to otherwise facilitate the functions of the Academy the membership shall be grouped into three broad Divisions:

A. Biological Sciences
B. Physical Sciences, Computer Sciences, and Mathematics
C. Social and Behavioral Sciences and Science Education

Section 2. Membership in Divisions. A member may join any Division of individual choice but shall not belong to more than one Division at one time. Membership in one Division shall not preclude participation in the program activities of other Divisions.

Section 3. Representatives to the Governing Board. The Nominations Committee shall nominate two candidates for Division Representative to replace those who are completing their term of service. Each Division will elect by mail ballot one Representative from the nominees. Each Representative shall serve for four years, but the terms shall be staggered so that a Representative from a given Division is elected every two years. In addition, two Representatives shall be elected from the membership at-large.

ARTICLE VII

SECTIONS

Section 1. Organization. Sections of the Academy shall be organized to represent the various fields, or disciplines, of science in each Division.

Section 2. Approval. The Governing Board upon recommendation by the Program Committee shall approve the establishment of Sections.

Section 3. Section Officers. Each Section shall elect annually a Chair and a Secretary to take office concurrently with the Officers of the Academy.

Section 4. Program Committee. The Chairs of all the Sections shall serve collectively as the Program Committee under the direction of the President-elect.

ARTICLE VIII

COMMITTEES

Section 1. Standing Committees. The President with the approval of the Governing Board shall appoint Members of the Standing Committees. As necessary, they shall be appointed to staggered terms so that no more than one third of each committee shall be replaced or re-elected at one time. Otherwise, each appointee shall serve for a term of three years. The President shall designate the Chair of each committee at the time committee appointments are

presented to the Governing Board. The eleven Standing Committees shall be:

1. A Committee on Membership that consists of at least three members. The Committee shall periodically review and update, if necessary, criteria and procedures for membership and provide leadership in devising and implementing recruitment activities. It shall be the goal of the Committee to increase membership through active programs of outreach to non-members.
2. A Committee on Publications that consists of the President, the Editor and Associate Editor of the *Journal*, and three members from the membership at-large as well as any other member(s) of the Executive Committee appointed by the President. The Editor shall serve as the Chair of the Committee, which shall recommend editorial policy for the *Journal* to the Governing Board.
3. A Committee on Legislation that consists of three members. The Committee shall be responsible for the consideration of legislation that affects the scientific interests of the Commonwealth of Kentucky and the Academy and. shall recommend to the Executive Committee appropriate action to be taken.
4. A Committee on Distribution of Research Funds that consists of at least six members. Members shall be chosen from disparate fields to provide broad representation of the different disciplines of the Academy. The Committee shall be responsible for evaluating research proposals, distributing funds, and shall have accountability in the use of research funds.
5. A Committee on Science Education that consists of six members. The Committee shall be responsible for promoting science education in the Commonwealth, especially in the primary and secondary schools. The Committee shall coordinate its activities to the extent feasible with the KJAS.
6. A Program Committee. The President-elect shall serve as Chair of the Program Committee. The Program Coordinator shall serve as Vice-Chair. Other members shall be Chairs of the Sections. This Committee shall be responsible for the program of the annual meeting and for any other meetings of the Academy.
7. A Committee on Awards. This Committee, consisting of the Vice President and three other members of the Governing Board, shall solicit and evaluate nominations for the awards of the Academy. The Vice President is responsible for presentation of the awards.
8. A Committee on Nominations and Elections. The Committee shall consist of three members and shall present nominations for all officers to be elected for the following year. Two candidates for each office shall be nominated and presented to the membership in appropriate form for mail balloting. Nominations of other candidates may be written in. Ballots for Division Representatives to the Governing Board shall be mailed only to members having identified with that Division. Ballots for the Representatives of the Membership-at-large to the Governing Board shall be mailed to all members of the Academy. It shall be the further responsibility of the Committee to canvass the membership to provide the Governing Board a list of members interested in serving as officers or on committees.
9. A Finance Committee consisting of the President, as Chair, the President-elect, Vice President, Executive Secretary, and Treasurer shall periodically review financial policies of the Academy and make recommendations to the Governing Board.
10. A Planning Committee that consists of the Past President and three other members. The Committee shall research meeting sites, make general program recommendations, identify activities that will strengthen the role in the Commonwealth and address other issues deemed appropriate by the Executive Committee. The Planning Committee shall make recommendations to the Governing Board.
11. A Public Relations Committee that consists of the Executive Secretary as Chair, two members from the Governing Board, and two members from the Membership-at-large. The Committee shall develop mechanisms to publicize Academy events, including annual and special meetings of KAS and the spring symposium of KJAS. The committee coordinates distribution of information on these events to the Web Page and Newsletter editors. The Committee shall be responsible for promoting the Academy in any appropriate manner as determined by the Executive Committee.

Section 2. Ad Hoc Committees. Ad hoc committees shall be named, as required, by the President and Executive Committee. The President shall designate the Chair of each committee at the time the committee appointments are announced.

ARTICLE IX

MEETINGS

Section 1. Annual Meeting. The Kentucky Academy of Science shall hold annually a fall meeting. In addition, the Governing Board upon the written request of twenty active members may call spring or other special sessions.

ARTICLE X

PUBLICATIONS

Section 1. *Journal of the Kentucky Academy of Science.* The Academy shall publish *the Journal of the Kentucky Academy of Science,* and other publications, authorized by the Governing Board.

Section 2. Recipients. Every dues-paying member of the Academy and each Chapter of the Junior Academy shall receive a copy of the *Journal.* Members of the Junior Academy who pay an appropriate fee, as determined by the Governing Board, shall receive a copy of the *Journal*

number that contains Junior Academy Symposium abstracts.

Section 3. Editor and Associate Editor. The President shall appoint the Editor and Associate Editor of the *Journal of the Kentucky Academy of Science* subject to the approval of the Governing Board. The Editor and Associate Editor shall be members of the Academy.

ARTICLE XI

KENTUCKY JUNIOR ACADEMY OF SCIENCE

Section 1. Relationship to Kentucky Academy of Science. The Kentucky Junior Academy of Science shall be a component of the Kentucky Academy of Science.

Section 2. Steering Committee. The President of the Kentucky Academy of Science shall appoint a Steering Committee for the Junior Academy of Science consisting of three members of the Kentucky Academy of Science and shall designate one of the three as Chair.

Section 3. Chair. The Chair of the Steering Committee shall serve as Director of the Kentucky Junior Academy of Science and as an *ex officio* member of the Governing Board of the Academy.

Section 4. Treasurer. The Steering Committee shall designate one of its members as Treasurer of the Junior Academy. The Treasurer shall be responsible for banking all dues paid and contributions made to the Junior Academy.

Section 5. Disbursements. Bills against the Junior Academy shall be paid only when authorized by the Chair of the Steering Committee.

Section 6. Audit The Accounts of the Treasurer of the Junior Academy shall be audited annually by a committee of two members, one to be appointed by the President of the Kentucky Academy of Science and one to be appointed by the Chair of the Steering Committee.

Section 7. Annual Report. The Chair of the Steering Committee shall make an annual report to the Kentucky Academy of Science. This report shall include a statement on major activities of the Junior Academy and a report on the finances of the Junior Academy as prepared by its Treasurer.

Section 8. Constitution. The Junior Academy shall operate under a Constitution approved by the Kentucky Academy of Science. All revisions of the Constitution of the Junior Academy shall be referred to the fall meeting of the Kentucky Academy of Science for approval.

ARTICLE XII

AMENDMENT OF CONSTITUTION

Section 1. Constitution. The Constitution of the Kentucky Academy of Science may be amended by mail ballot if approved by two-thirds of the members responding, and if at least ten percent of the members have voted. The Constitution may also be amended at any regular meeting by two-thirds of the members present, provided a notice of said amendment has been sent to all members at least thirty days in advance of the meeting.

BYLAWS

I. Items of Business. The following items may be included in the order of business for general or Governing Board meetings:

1. Call to order.
2. Reports of officers.
3. Reports of the Executive Committee.
4. Reports of the Standing Committees.
5. Reports of the ad hoc Committees.
6. Appointment of ad hoc Committees.
7. Unfinished business.
8. New business.
9. Election of officers and representatives.
10. Program.
11. Adjournment.

II. Quorums. Forty members shall constitute a quorum of the Academy for transaction of business. Nine members shall constitute a quorum of the Governing Board. Four members shall constitute a quorum of the Executive Committee.

III. Membership dues. Annual membership dues for Regular Members shall be fixed by recommendation of the Governing Board and approval of the membership by simple majority. Other categories of membership dues shall be fixed by the Executive Committee and the Governing Board and shall be published from time to time in Academy publications.

IV. Endowments and Life Membership. Life membership monies shall be credited to an endowment account. Any member may become a Life Member by designating a one-time donation, the sum of which is at least equal to the life membership fee

V. Elections. Balloting shall be by mail, allowing at least six weeks between mailing of the ballots by the Secretary and their return by October 15. The candidate who receives a simple majority of the ballots cast shall be declared elected. The Committee on Nominations shall be responsible for the election process.

VI. Members in Arrearage. Members who have allowed their dues to lapse for two consecutive years, having been notified of their arrearage by the Treasurer, shall have their names stricken from the membership list. Members in arrears shall not receive the *Journal*

VII. Submitting Titles and Abstracts. All titles and/or abstracts of same, intended for presentation on any program of the Academy, must be submitted to the Section Secretary or Section Chair prior to the meeting at the designated times.

VIII. Establishing Rotation. To establish a proper rotational basis for terms on Standing Committees, the first

year one member shall be appointed for a three-year term, one for a two-year term, and one for a one-year term.

IX. Representative to AAAS/NAAS. The President shall appoint a representative to the American Association for the Advancement of Science and the National Association of Academies of Science.

X. Scientific Organizations. Any scientific organization in the Commonwealth of Kentucky in a field of science recognized by the American Association for the Advancement of Science may affiliate with the Academy.

XI. Division and At-large Representatives to the Governing Board will be phased in over the four years following ratification of this Constitution and Bylaws. The Governing Board will establish the mechanism for this phase-in.

XII. Amendment of Bylaws. These Bylaws may be amended or suspended by a two-thirds vote of the members present at any general meeting or Governing Board meeting, or by a two-thirds majority of members responding to a mail ballot, provided that at least ten percent of the members have voted.

KENTUCKY ACADEMY OF SCIENCE ORGANIZATION

GOVERNING BOARD

Executive Committee
- President
- President-elect
- Vice President
- Past President
- Secretary
- Treasurer
- Executive Secretary (*ex-officio*)
- Editor (*ex-officio*)

Other Members
- Division Representatives—6
- At-Large Representatives—2
- Program Coordinator (*ex-officio*)
- Director, Junior Academy of Science (*ex-officio*)
- Newsletter Editor (*ex-officio*)
- Web Page Editor (*ex-officio*)
- AAAS/NAAS Representative (*ex-officio*)

STANDING COMMITTEES

1. Membership
2. Publications
3. Legislation
4. Research Funds
5. Science Education
6. Program
7. Awards
8. Nominations and Elections
9. Finance
10. Planning
11. Public Relations

INSTITUTIONAL AFFILIATES

Fellow

University of Kentucky

Sustaining Member

Campbellsville University
Eastern Kentucky University
Murray State University
Northern Kentucky University

Member

Berea College
Centre College

Associate Member

Transylvania University

INDUSTRIAL AFFILIATES

Associate Patron

Touchstone Energy

Associate Member

Wood Hudson Cancer Research Laboratory, Inc.

CONTENTS